

INFLUENCE OF SUCTION PRESSURE
ON THE CAPACITY OF A SIX - CYLINDER
PACKARD ENGINE

BY

F. G. COOBAN

R. C. PALMER

E. STEPANEK

ARMOUR INSTITUTE OF TECHNOLOGY

1915

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Influence of suction
pressure on the capacity

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INFLUENCE OF SUCTION PRESSURE ON
THE CAPACITY AND ECONOMY OF
A SIX-CYLINDER PACKARD
ENGINE

A THESIS

PRESENTED BY

FRANK G. COOBAN
ROGER C. PALMER
EMIL STEPANEK

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

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HAVING COMPLETED THE PRESCRIBED COURSE OF STUDY IN

MECHANICAL ENGINEERING

MAY 27, 1915

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Chicago, Illinois.

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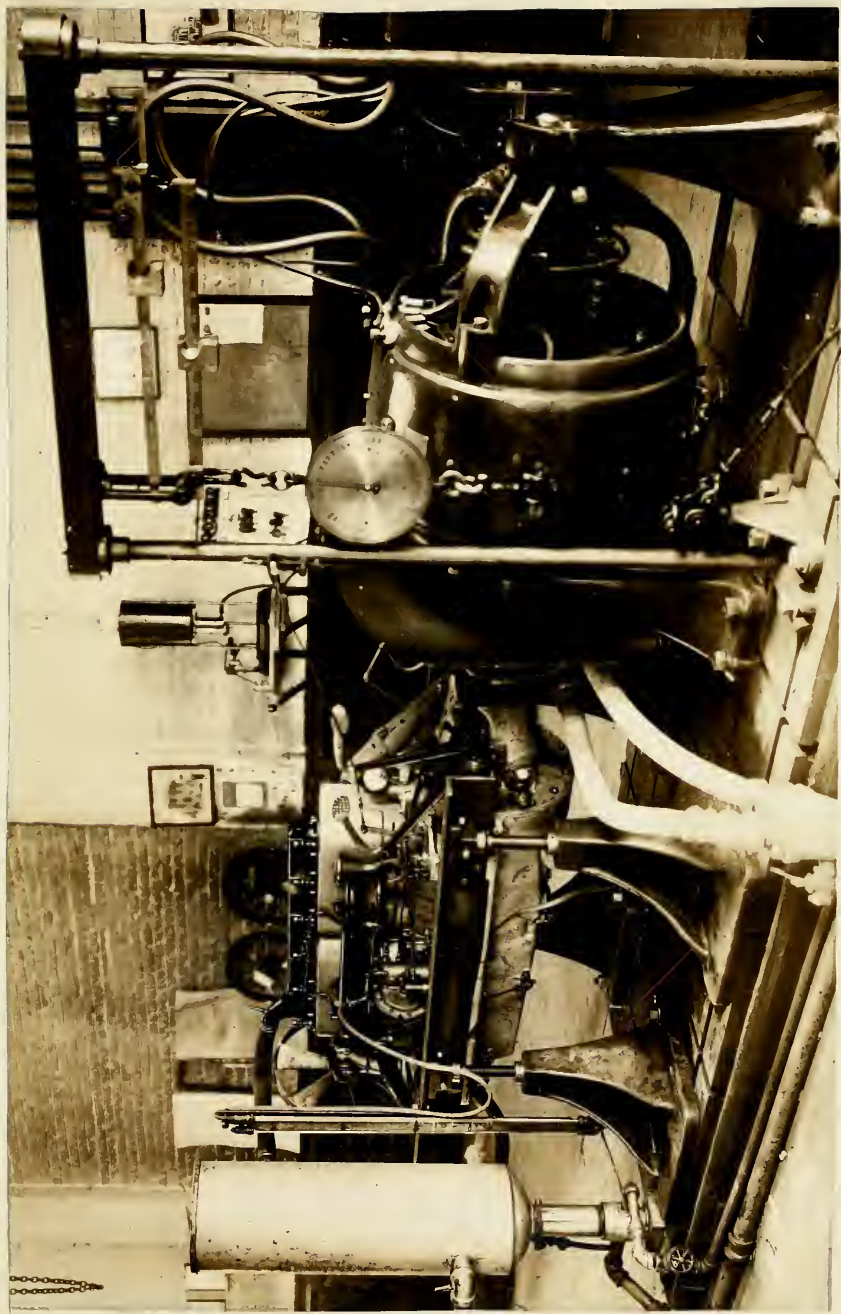
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1895-1896

1. Introduction
2. The first year of the war
3. The second year of the war
4. The third year of the war

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14. The fourteenth year of the war
15. The fifteenth year of the war
16. The sixteenth year of the war
17. The seventeenth year of the war
18. The eighteenth year of the war
19. The nineteenth year of the war
20. The twentieth year of the war



PART I.

A Short Treatise on the Packard 38
Motor and a Description of the
Apparatus used in testing it.

PART I.

A Short Treatise on the History of
the People of the
United States

INTRODUCTION.

The object of this test is to determine the effect on the economy and power of a Packard "38" Motor by varying the suction pressure. Since the advent of the dynamometer in automobile motor testing, it has been found advisable in order that testing conditions may be uniform, to have all motors tested with full advanced spark and wide open throttle. This has caused some discussion as to effect of having the throttle in different positions, and has led to the investigation mentioned in the first sentence.

INTRODUCTION

The object of this test is to determine the effect on the economy and power of a "33" motor of varying the excitation. Since the nature of the dynamometer in this mobile motor testing, it has been found advisable in order that testing conditions may be uniform, to have all motors tested with full advanced spark and wide open throttle. This has caused some discussion as to effect of varying the throttle in different positions, and has led to the investigation mentioned in the first sentence.

The Packard "38" Motor.

The Packard "38" is a six cylinder four cycle L-head motor, the cylinders having a 4 inch bore and 5-1/2 inch stroke, thus giving a bore stroke ratio of 1.375, and a horse power ratio S. A. E. of 38; the cubic displacement in each cylinder is 69.115 cubic inches, and the clearance volume 21.77 cubic inches. The cylinders are cast in blocks of three.

The valves are all on the right side of the motor, the exhaust head also connecting on this side. The inlet manifold is carried on the left side, and is split into three sections, each passing between two of the pairs of cylinders, one through the water jacket to the right side. The manifold connections, which are four in number, bolt to the left side of the cylinder casting and from these connecting points the mixture is distributed to the intake ports.

The inlet manifold has a straight horizontal main section, from which the cylinder

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connections pass and a short section at right angles connecting with the carbureter. The manifold is water jacketed along its horizontal length; this together with added heating that the fuel receives in passing through the water jacket spaces in the cylinder, helps the efficiency of the motor considerably.

The exhaust manifold is of the double type known as the Siamese arrangement, in that each block of the three cylinders has a separate passage; that for the rear block is cast integrally with the front header, however, there is a connection between the two as far back as the flange where the exhaust pipe joins.

The lubrication is by a force feed from a gear driven pump located in the crank case. After being strained the oil is forced by the pump through an external pipe up to another strainer mounted at the forward end of the motor. It then flows down to the camshaft through an internal passage within that part of the forward end of the crank case which forms the rear of the timing gear housing.

connections pass and a short section of right
angle connecting with the crankshaft. The
rod is water jacketed along its entire
length; this together with water flowing
the fuel receives its pressure through the water
jacket spaces in the cylinder, helps the efflu-
ency of the water circulation.

The exhaust manifold is of the double type
known as the Diamond arrangement, in the
block of the three cylinders and a separate
passage; that for the rear block is cast into
itself with the first header; however, there
is a connection between the two as far back as
the flange where the exhaust pipe joins.

The lubrication is by a forced feed from
a gear driven pump located in the crank case.
After being relieved the oil is forced by the
pump through an internal pipe up to another
strainer mounted at the forward end of the
motor. It then flows down to the cylinder
through an internal passage within the case
of the forward end of the crank case which
forms the rest of the timing gear housing.

Holes drilled in the bearings communicate with the hollow center of the camshaft and as the latter revolves these register with the main lead just mentioned; this applies to the other bearings as well. Leads in the crank case web carry oil down to the crank shaft bearing and then through leads it is brought down to the connecting rod bearings. The connecting rods are also drilled and from here the oil is led to the piston pin bearings through the rods.

The carbureter is of the firm's own design, and manufacture, combining float feed, automatic mixture regulation for all motor speeds and uniform temperature. It has a water jacketed cylindrical mixing chamber, the auxiliary air inlet being automatically regulated for varying speed by a spring controlled poppet valve, the latter being controlled by a small lever which regulates the spring tension for varying atmospheric conditions. In connection with this carbureter is a hydraulic governor, consisting of a diaphragm enclosed in a compartment. The pressure of the water

system bears on one side of the diaphragm while the other side of the diaphragm is interconnected with the carbureter throttle, so that when the water pressure is greatest, due to a higher engine speed, the diaphragm is bulged outward and through a rod connection partly closes the throttle, thereby tending to maintain a uniform motor speed. The motor is cooled by positive water circulation through cellular motor cylinder water jackets by a gear driven centrifugal pump; together with a belt driven ball bearing fan.

Ignition, which is entirely independent of the lighting and cranking, is provided by a Bosch duplex system, using a single set of spark plugs. The high tension Bosch duplex magneto sends the secondary current directly to the spark plugs.

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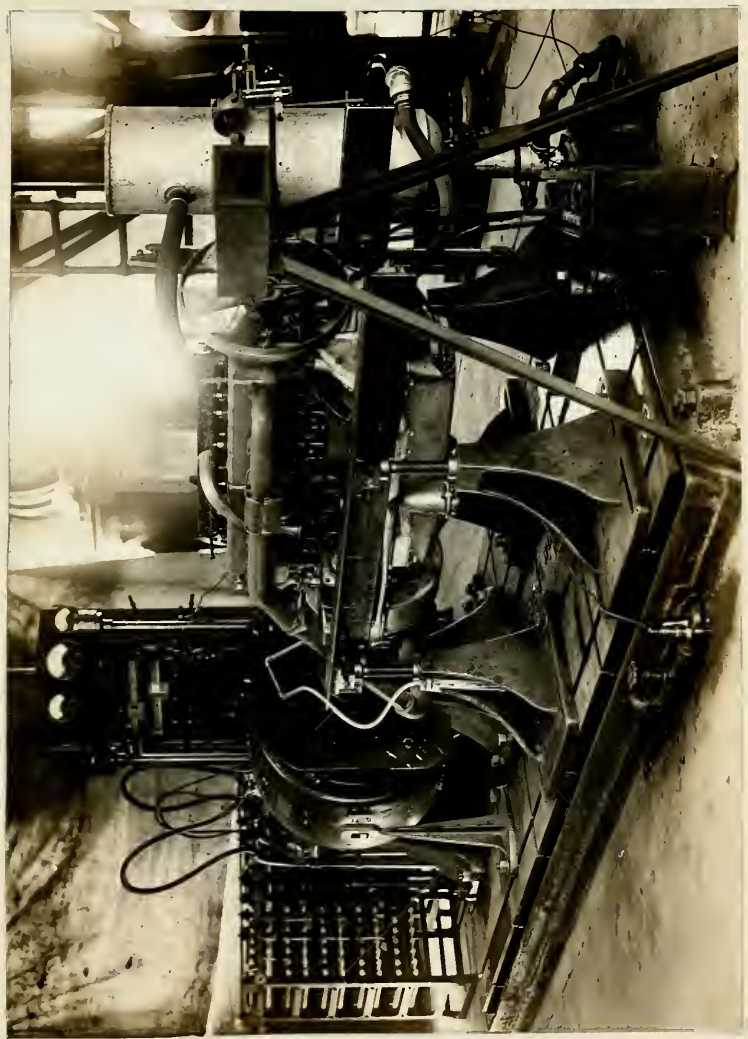


Fig. 2

Description and Operation of the Various Testing Equipment.

The Sprague electro-dynamometer was used in the testing of the Packard motor. Briefly, it consists of a one-hundred horsepower direct current inter-pole generator mounted on a cast iron bed plate. The torque is taken from knife edges screwed to the frame of the generator and transmitted through a drawbar and spring balance scales to a set of chatillion scales. The length of this arm is equal to 1.315 feet, so that the torque multiplied by the R. P. M. divided by 4000 gives the horse power developed. Ways are cast in the bed plate for holding down motor stands; these stands can be adjusted so as to accomodate any size motor and have the engine lined up with the armature shaft in such a way that a flexible coupling can be inserted between the two. The switchboard is mounted on pipe stands within reach of the scale beam. It contains the control switches, field rheostat circuit breaker, ammeter and voltmeter, for the electro-tachometer. In order to maintain a

OUT TO 111-1000 AND NOT EXIST
JAMES W. 111-1000

steady field flux that will not vary with the speed, the field is separately excited. The drawing at the back of this thesis shows the electrical connections of the apparatus.

The following instructions for operating were sent out with the machine by the Sprague Electric Works.

Instructions for
Operating The Sprague
Electro-Dynamometer
"Preliminary Adjustment."

"The dynamometer should first be balanced at a standstill and before connecting it to the engine to be tested. Care should be taken that the incoming leads to the dynamometer frame do not exert a pull which interferes with the pull of the dynamometer frame on the beam scale. When a balance has been obtained with the beam scale reading zero, connect the engine to be tested."

Starting.

"Leave all the single pole switches open. See that the field rheostat is turned as far as it will go to the full field position. Close the field switch and be sure that there

THE FIRST PART OF THE BOOK IS A HISTORY OF THE
THE SECOND PART OF THE BOOK IS A HISTORY OF THE
THE THIRD PART OF THE BOOK IS A HISTORY OF THE
THE FOURTH PART OF THE BOOK IS A HISTORY OF THE
THE FIFTH PART OF THE BOOK IS A HISTORY OF THE

10-10-1944

101 111 121 131 141
 151 161 171 181 191
 201 211 221 231 241
 251 261 271 281 291

is a current in the field circuit. Trip the circuit breaker and put both interlocking switches to the right. Close the single pole switches in the upper row one at a time. The machine should start after two or three switches have been closed."

Operation as Motor.

"If it is desired to increase the speed in order to take a friction test at higher speeds than that of starting, continue closing the switches in the top row one at a time. When all of the top switches are in, close the circuit breaker which in turn short circuits the resistances. If speed is to be still further increased, open all the single pole switches and slowly turn the field rheostat handle so as to weaken the field.

PRECAUTION. Do not weaken the field before the circuit breaker has been closed and all single pole switches open."

Operating as Generator.

"Before operating the dynamometer as a generator, see that the field rheostat is

turned to the full field position and two or three switches in the top row closed. When the engine to be tested has begun to run under its own power, throw the lower transfer switch to the left. The load is now increased by closing the switches in the top row and at the same time supplying more power to the motor being tested. Variation in speed is obtained by the field rheostat."

"To load the dynamometer at speeds below one half of normal speed as stamped on the dynamometer name plate, close three or four switches in the lower row, leaving the switches in the top row closed, and throw the upper half of the transfer switch to the left. The load may now be increased by closing the switches in the lower row one at a time."

"Care should be taken to manipulate the load switches and field rheostat so that the current does not exceed three hundred amperes and the voltage on high speed load does not exceed 250 volts continuous or 300 volts for five minutes. In increasing the load when

[illegible]

running at half the normal speed, if the current rises over three hundred amperes strengthen the field and open a few switches. Do not allow the voltage when running at half of normal speed to exceed 125 volts.

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Fig. 3



Gas Consumption.

One of the hardest problems presented was that of obtaining accurate fuel consumption for short runs of two or three minutes each, where the amount of fuel consumed was so small as to make it impossible to ascertain the consumption by simply the difference in weight before and after the run. In order to overcome this a gasoline tank was installed as shown in Figure 1

It consisted of an inner and outer cylinder, the inner one capable of holding about two pounds of gasoline and the outer about twenty five pounds. The stop cocks could be so arranged that both tanks would feed the motor at once or just the small one; the latter was found to be sufficient for any of the runs made in the test. As soon as the small tank became empty the stop cock could be opened and the small tank replenished from the large one, after which the connection could again be closed. By a few small gear wheels a float operated a dial which when calibrated, indicated the

amount of gasoline used; this float also indicated through a tall gauge glass the amount of gas in the large cylinder; after a number of calibrations, it was found that for one complete turn of the dial .280 pounds of fuel would run from the tank. The entire apparatus was mounted upon a scale from which amounts of gasoline used both in the calibration of the tank and the tests of the motor could be fairly accurately verified, due to the fact that when the scale beam reached a definite position points on the beam would come in contact with mercury placed in small cups and in so doing complete an electrical circuit causing a bell to ring. Data relative to the calibration of this tank can be found under preliminary observations page 20. This gasoline tank was placed about ten feet from motor and about six feet from the floor level, the connection being made through two flexible tubes connected by a pipe passing underneath the floor.

1. The first part of the report is a general introduction to the subject of the study. It discusses the importance of the study and the objectives of the research.

Cooling Apparatus.

Due to the fact that the motor as tested had no radiator, the cooling water was supplied from a tank placed at the side of motor, best shown in Figure 1. The amount of incoming cold water could be regulated by a valve, while the amount of water pumped by the motor depended of course on the speed of the latter. Data and curves taken on this item are shown later in this thesis, the highest amount taken care of by the pump being nearly 36 gallons per minute at about 1700 R. P. M. The temperature of the inlet and outlet water were taken and in general it was found to be between 100° F. and 150° F.

There is no doubt that the information
contained in this report is reliable and
that it is a true and accurate
statement of the facts. The information
was obtained from a reliable source
and is being furnished to you for
your information. It is not to be
distributed outside your office.
Very truly yours,
[Signature]

Manograph.

A manograph or optical gas engine indicator was used in obtaining some of the data. It was driven off the crank shaft and was connected directly to it where the shaft protruded from the front of the motor. Illumination was furnished by a small arc-light focused on the eye piece. It was designed and manufactured by I. Carpentier of Paris, France. This instrument was calibrated with the aid of a compressed air tank of known pressure. The results of this calibration are shown on the manograph cards at the back of this report, while the position of this manograph is best shown in Figure 2 .

The speed counter used was of the simplest type; the counter merely being pushed into the end of dynamometer motor shaft and readings taken for periods of one half minute or minute as the case demanded.

Two mercury manometers were used in this test; one for measuring the pressure at the in-

take manifold and the other placed in the exhaust line, from the front block of cylinders. They were both of the "U" type; the one on the intake manifold being capable of measuring about twenty inches of pressure, while that on the exhaust measured about eight inches pressure. The manometer on the intake manifold was connected by flexible rubber tubing to a small stop-cock which was in turn connected to a small brass pipe brazed on the manifold. The exhaust manometer was simply connected by a curved pipe and flexible tubing, the latter two connected by a small cock.

This concludes the principal apparatus used in this test, such items as the types of thermometers used, watches, etc, are of little consequence in a test of this kind, as it is merely desired to keep things constant for a very short period of time. The maximum time for any run being about three minutes.

PART II.

Observations and Tests made with Sample Calculations leading to Definite Results.

Page 11

THESE ARE THE RESULTS OF THE
ANALYSIS OF THE SAMPLES
OF THE SUBSTANCE.

Preliminary Observations.

Introduction.

Before the actual test runs were made on the motor several preliminary observations were necessary; briefly speaking, a determination of the range of ignition was made as well as the valve timing. The gasoline tank and water pump were calibrated and the clearance volume of cylinder No. 1 was determined. The method pursued in making these determinations together with the figures resulting from the latter are shown on the following pages.

Determination of the Range of Ignition.

The spark lever was set to the full retard position, after which the engine was turned over by hand until cylinder number one was at top dead center and on the compression stroke. In this position the cylinder was ready to fire its charge of gas. The cover on the breaker box was disconnected and a thin piece of paper inserted between the platinum points, after which the motor was turned backward or forward

Chrysomelidae

THE STATE OF NEW YORK
IN SENATE
JANUARY 1, 1901.
REPORT
OF THE
COMMISSIONER OF THE LAND OFFICE
IN RESPONSE TO A RESOLUTION
PASSED BY THE SENATE
MAY 1, 1899.
ALBANY: J. B. LIPPINCOTT & CO., PRINTERS.
1901.

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until the points were closed and the paper held securely. The motor was then turned over slowly until the points just released the paper; this was the point of ignition for the retard position of the spark lever. A mark was made on the flywheel opposite the indicator and the distance measured on the flywheel from the mark to the top dead center of the corresponding cylinder. The paper was replaced between the breaker points and the spark lever advanced a trifle. The flywheel was turned back half of a revolution and then brought forward slowly until the points just began to separate. This was the point of ignition for full advance of the spark. A mark was made on the flywheel opposite the indicator as before, and the distance measured from the mark to the top dead center.

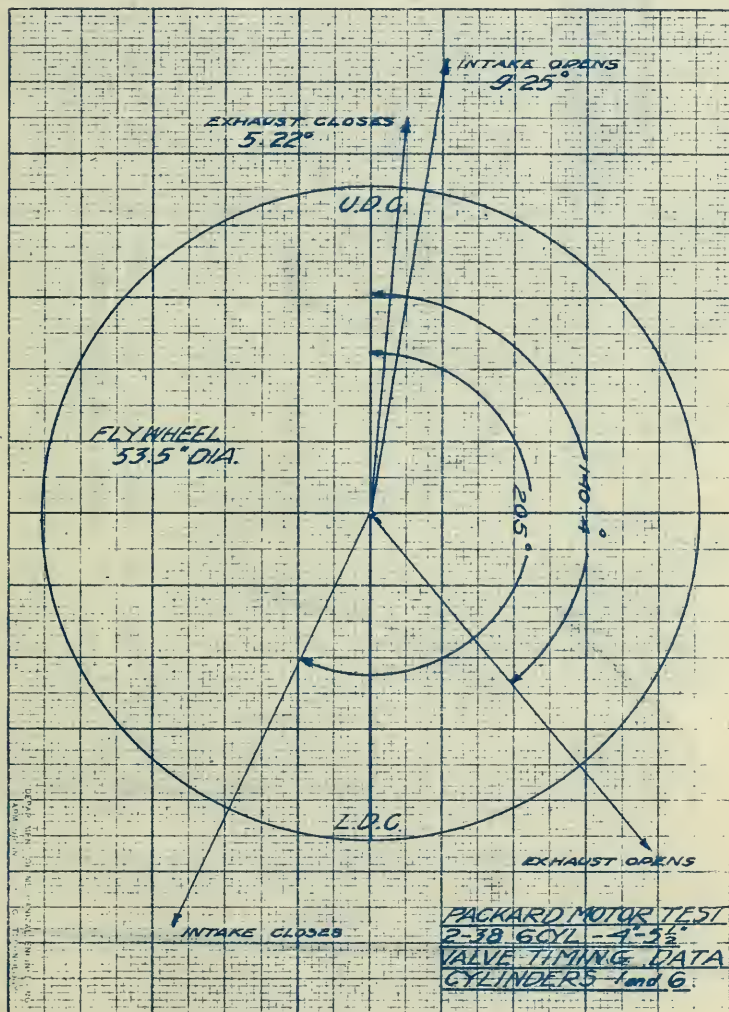
To obtain these results in degrees as was done it was necessary to multiply the distance measured by 360 and divide this by the circumference of the flywheel, the latter being determined by slipping a tape around the outside

of the flywheel. The spark lever was set at various positions and the points of ignition determined for each position as above.

Valve Timing.

Before the valves were set the clearance was determined. This should be about .004 of an inch on the intake valve and about .005 of an inch on the exhaust valve. The method of setting the clearance was as follows:

A gauge of the proper thickness was inserted between the intake valve stem and the push rod, after which the motor was turned over until the mark "Inlet Valve Opens" on the flywheel appeared opposite the indicator mark. The valve should just begin to open at this point. If the valve should open before the mark on the flywheel and indicator coincide, the length of the push rod can be adjusted. If the valve opens too late, the valve tappets can be adjusted until the right opening is obtained. The engine was then turned over by hand until the stem rested on the low part of



CRANK PIN POSITION

60 120 180 240 300 360 420 480 540 600

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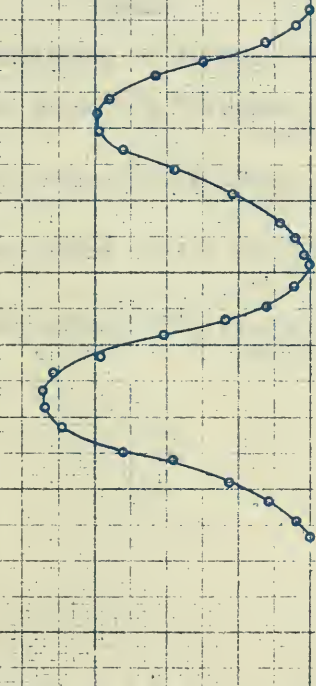
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INCHES



PACKARD MOTOR TEST
2-38-60X 4x5 1/2
VALVE LIFT DIAGRAM
APRIL 9-1915

the cam at which time the thickness gauge should be extracted from the tappets. If the setting was made properly the gauge will just fill the clearance space between the valve stem and push rod.

Data.

Circumference of Flywheel 53-1/2 inches

Intake opens 1-3/8 inches. equals 9.25°
degrees L.U.D.C.

Intake closes 3-3/4 inches L.L.D.C. equals
205 degrees L.U.D.C.

Exhaust opens 19-1/2 equals 140.4° degrees
L. U. D. C.

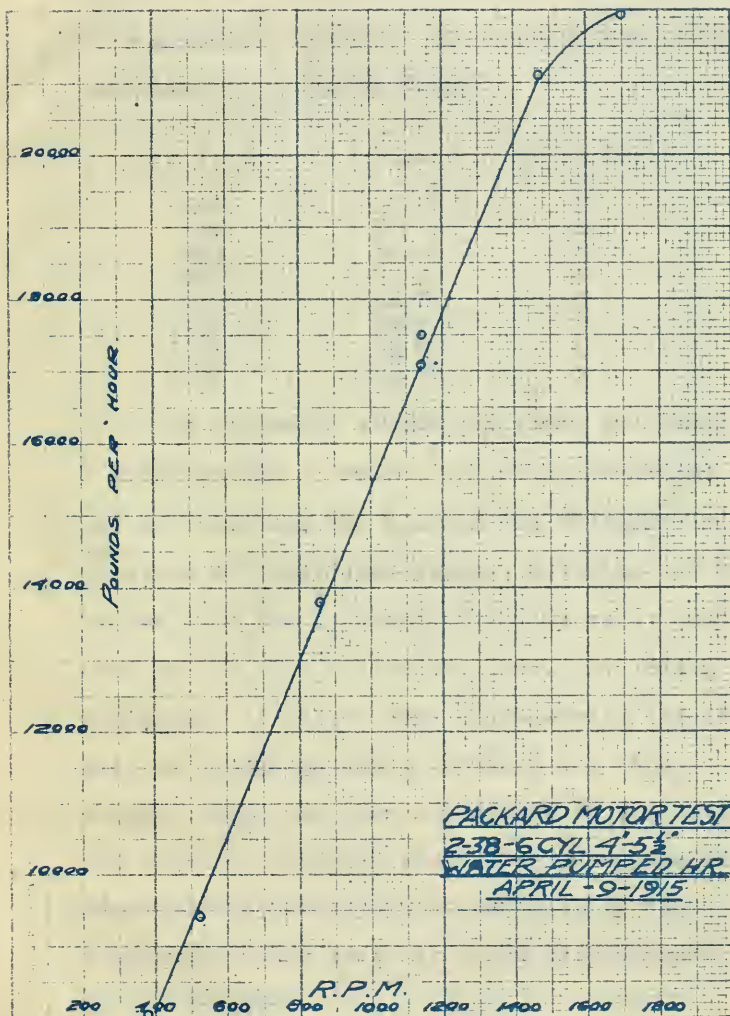
Exhaust closes 7/8, equals 5.22 degrees
L.U.D.C.

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The same scheme was carried out for the exhaust valve after the clearance had been set, the motor was turned over until the intake valve on any particular cylinder began to open. The distance was measured on the flywheel from top dead center to the mark made as explained above. The motor was again turned over until the exhaust valve began to open and the distance again measured from the mark to the lower dead center. The same procedure was gone through in determining the closing points of the intake and exhaust valves. The results appear below.

The determination of the amount of cooling water pumped at different speeds was made as follows; a three way valve was placed in the outlet line leading from the motor to the cooling water tank. The engine was then run at different speeds and the water coming from the motor was allowed to flow for five seconds into a receptacle placed on weighing scales. In this way the amount of water pumped per minute for each speed was determined by multiplying the



weight of water flowing into the receptacle for five seconds. The data and curve for this determination are shown below.

R.P. M.	Lbs.	Time sec.
366	11.25	5
532	13.	5
860	19.25	5
1004	21.5	5
1178	23.75	5
1466	29.5	5
1532	31.5	5
1710	30.5	5

The clearance volume was found by taking a known weight of water, and after removing the cylinder cap and placing the cylinder in question on upper dead center, allowing the water to run into the cylinder until the water just came to the head of the cylinder. By rating the weight of water used, and assuming the density as unity the cubic contents was easily found. Since the bore and stroke of the motor are known the percent clearance volume can be determined by multiplying the ratio of the clearance volume over the cubic displacement by one hundred.

Some difficulty was found in calibrating

the gasoline tank due to the fact that the small brass gear wheels operating the dial pointer were not smoothly finished and caused the pointer on the dial to stick, thus giving incorrect readings. After this defect had been adjusted the work of calibrating the tank was as described below. The tank was first filled with gasoline and its weight noted. The scale bob was then placed one pound under this weight and the stop cock from the small tank opened and the gasoline allowed to run out. Due to the fact that the scale was electrically connected, a bell was rung the instant the amount of gasoline running from the tank had reached one pound. During this period the number of turns and fraction thereof that the pointer made were noted. These determinations were made a number of times, for different weights of gasoline. From this data the amount of gasoline used for each turn of the pointer could be calculated by dividing the weight of gasoline allowed to run out of the tank, by the number of turns made. From the data obtained it was found that .28 of a

the preceding cases in the fact that the same
was seen in the preceding case. The latter was
not smoking during the time the patient was
the first to smoke, and, being, therefore, the first
after this defect had been observed the first of
patients. The case was as reported before.
The case was first listed with cocaine and the
weight noted. The patient was then changed
and placed under this weight and the new weight
from the weight then noted and the difference
allowed to be noted. The weight was then
again was electrically measured, which was
long the patient was placed in the same position
from the time the patient was placed in the
this period the weight of the patient was
the same. The weight was then noted. The
determination was made by the patient's weight
different weight of cocaine. From the same
the amount of cocaine and for each case
the patient could be determined. The
the weight of cocaine was then noted. The
the case, by the patient's weight. The
the case was then noted. The case was

pound of gasoline ran from the tank for each revolution of the pointer. This result may not be absolutely correct, but it is the average of a great many calibrations and therefore may be considered a value which will give fairly accurate results as far as the actual economy of the engine is concerned, and as far as relative economy is concerned between the different throttle pressures it may be considered correct. The latter economy was the one desired in the test.

Calibration.

Gasoline Tank.

Wt. Lbs.	Turns.	Lbs. Turn.
1	3.69	.272
1	3.56	.281
1	3.54	.282
1	3.63	.275
1	3.70	.270
2	7.15	.280
2	7.13	.281
2	7.22	.278
2	7.17	.279
2	7.10	.281

Average of the total is equal .28 pounds per turn of the dial.

Engine Tests.

The tests of the motor are listed under two general heads, namely: Power and Economy Runs, and Friction Horsepower Runs. The former are eight in number and the latter seven. Besides these two sets of data compression runs for each suction and a number of speeds were made, the curves, manograph cards and data for each of these runs being shown at the back of the thesis.

The tests at the different suctions were run at speeds varying from 300 R. P. M. to 2000 R. P. M., generally five different speeds were taken together with the other items shown on the log sheets. The gasoline consumption was obtained as described under preliminary observation, in almost all cases three readings being obtained in order to check the results. The same might be said of R. P. M. readings, which were generally two in number each being made for 30 seconds.

The friction horsepower runs were made as

described from speeds of 300 R. P. M. to 1000 R. P. M., and the curve for the horse power thereafter assumed. The reader is referred to the discussion of results and curves for a more complete analysis of the results of the test.

The method used in calculating the different items of the log sheet can best be shown by an actual computation. Run No. 1 with wide open throttle will be carried through as a sample computation.

The log sheet shows that the average time required for 664 revolutions of the motor was one minute.

The torque was 173 lbs, which gives the horse power developed as $173 \times 664 \div 4000$, equals 28.8.

The torque in ft. lbs is equal to the torque multiplied by the length of the arm in ft., which gives 173×1.315 equals 227.5.

The friction horsepower as taken from the friction curve is equal to 4.0.

The indicated horsepower then is the sum of the developed or the brake horse power plus

described from points of view of the power
 M. P. M., and the curve for the power
 theoretical aspect. The power is related
 to the dimension of the vessel and curves for
 some specific analysis of the results of the
 tests.

The method used in calculating the air-
 frame losses of the engine can be shown
 by an actual calculation. For the 1.5 liter
 engine the results will be carried through as a
 sample calculation.

The log shows that the average
 time required for one revolution of the motor
 was 0.0015 seconds.

The torque was 175 lbs, which gives the
 torque power developed as $175 \times 50 \div 6000$,
 equals 1.45.

The torque in ft. lbs is equal to the
 torque multiplied by the length of the arm in
 ft., which gives 175 X 0.15 equals 26.25.
 The indicated horsepower can be found from
 the indicated torque is equal to 26.25.

The indicated horsepower then is the sum
 of the developed and the indicated power.

the friction horsepower or 28.8 plus 4.0, equals 32.8 I. H. P.

The Motor used .56 lbs. of gasoline in 88 seconds, or 22.9 lbs. per hour, thus $.56 \times 3600$ equals 22.9 lbs per hour.

The gasoline consumption per B. H. P. is $22.9 \div 28.8$ equals .824 lbs.

The density of the gasoline in degrees Baume was found to be .60.

From the equation for low testing value of gasoline, namely:

B. T. U. per lb. equals 17030 plus 40 (B-10).

Where (B) is the Baume reading, the heating value of the gasoline was found to be 19030 B.

T. U. per lb.

The B. T. U. supplied per hour to the motor is equal to

19030×22.9 equals 436500 B. T. U.

The heat equivalent of one horsepower is 2545 B. T. U. per hour. Then the percent of the total heat which is utilized as B. H. P. is equal to $\frac{2545 \times 28.8}{436500} \times 100$ equals 16.8%.

the station however on 11.2.1944, 10.4.1944, 10.5.1944

11.6.1944, 11.7.1944

The first part of the report is as follows:

On 11.7.1944, 10.8.1944, 10.9.1944, 10.10.1944, 10.11.1944

11.12.1944, 11.1.1945, 11.2.1945

The second part of the report is as follows:

11.3.1945, 11.4.1945, 11.5.1945

The third part of the report is as follows:

11.6.1945, 11.7.1945, 11.8.1945

11.9.1945, 11.10.1945, 11.11.1945

11.12.1945, 11.1.1946

11.2.1946, 11.3.1946, 11.4.1946, 11.5.1946, 11.6.1946

11.7.1946, 11.8.1946, 11.9.1946, 11.10.1946, 11.11.1946

11.12.1946, 11.1.1947, 11.2.1947, 11.3.1947, 11.4.1947

11.5.1947, 11.6.1947, 11.7.1947

11.8.1947, 11.9.1947, 11.10.1947, 11.11.1947, 11.12.1947

11.1.1948, 11.2.1948, 11.3.1948

11.4.1948, 11.5.1948, 11.6.1948, 11.7.1948, 11.8.1948

11.9.1948, 11.10.1948, 11.11.1948, 11.12.1948, 11.1.1949

11.2.1949, 11.3.1949, 11.4.1949, 11.5.1949, 11.6.1949

11.7.1949, 11.8.1949, 11.9.1949, 11.10.1949, 11.11.1949

11.12.1949, 11.1.1950, 11.2.1950, 11.3.1950, 11.4.1950

11.5.1950, 11.6.1950, 11.7.1950

From the calibration curve of the water pump we find that it circulates 11250 lbs of water per hour at the above speed.

The temperature difference was equal to 9 degrees Fahrenheit, hence the heat lost to cooling water is equal to 9 X 11250 equals 101250 B. T. U. and the percentage of heat lost to the jacket water is equal to

$$\frac{101250 \times 100}{436500} \text{ equals } 26.1$$

Of the total heat supplied 45. 1% has been accounted for, leaving 57.1% lost to radiation, exhaust, etc.

from the bottom of the water
 to the top of the water
 water for both of the water
 The temperature difference was equal to
 0.1 degrees Fahrenheit, which was about 0.1
 degree Celsius. The water in the tank was
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 water in the tank was about 1.1 degrees Celsius.
 The temperature of the water in the tank was
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of the total heat capacity of the water
 was about 1.1 degrees Celsius. The temperature
 of the water in the tank was about 1.1
 degrees Celsius.

Discussion of Results from Motor Tests.

The data and curves resulting from the tests of the motor show clearly that a distinct relation exists between the suction pressure and the power and economy.

The economy curves show the following facts, that the gasoline consumption per hour decreases with the mercury depression, but at the same time the actual gasoline consumption per B. H. P. hour increases with the mercury depression.

In regard to the power, it can be said that the torque, B. H. P. and I. H. P. decrease an appreciable amount for each increase in the intake depression. The best B. H. P. obtained during the entire test was sixty three, the latter remaining almost constant from 1700 R. P. M. to 2000 R. P. M.

The M. E. P. - R. P. M. curves show the same tendency as the H. P. curves, namely, that of decreasing as the depression increases, the maximum M. E. P. for each suction being

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reached from the speeds of 600 R. P. M. to 800 R. P. M.

The mechanical efficiency curves are especially interesting, due to the wide range of value obtained, the wide open throttle run showing an efficiency of 73% at 1800 R. P. M. and 89% at 400 R. P. M., while the 16inch suction shows values ranging from 10% to 63% for the same speeds as above.

In the matter of efficiency, the thermal, heat lost in cooling water and the heat lost in the exhaust evidently do not follow any direct law, but are influenced by outside conditions which cannot be altered and the result therefore could not be discussed with any degree of satisfaction, except to say that the thermal efficiency and heat lost in the exhaust are of values generally accepted as correct in motor practice.

From the manograph cards shown, one common fault is at once noticeable, that of slow burning of the gases. This is, however, to be expected from the type of motor used, as it is considered an inherent fault of the "L" head

reached from the records of 600 A. V. 1. 1. to 100

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type of motor.

From the compression cards it can be seen that the compression increases as the suction depression decreases, and also that the general form of the curve drawn through the highest points of the compression lines follows very closely the torque curves spoken of on a former page.

In conclusion the reader is referred to the numerous curves and log sheets appearing at the back of this thesis, and which show more clearly than can be described not only the little individual characteristics of each suction and speed, but also the relation which exists between the suction depression and the power and economy.

type of motor.

First the compressor is run at low speed
and the temperature indicator is run slowly
and the pressure indicator; and the pressure
indicator is run slowly and the temperature
indicator is run slowly and the pressure
indicator is run slowly and the temperature
indicator is run slowly and the pressure

indicator.

In operation the motor is referred to
the indicator and the pressure indicator
at the top of the scale, and which shows the
indicator can be referred not only to the
indicator but also to the pressure indicator
and the pressure indicator which shows the
indicator and the pressure indicator and the pressure

indicator.

PART III.

Data sheets.

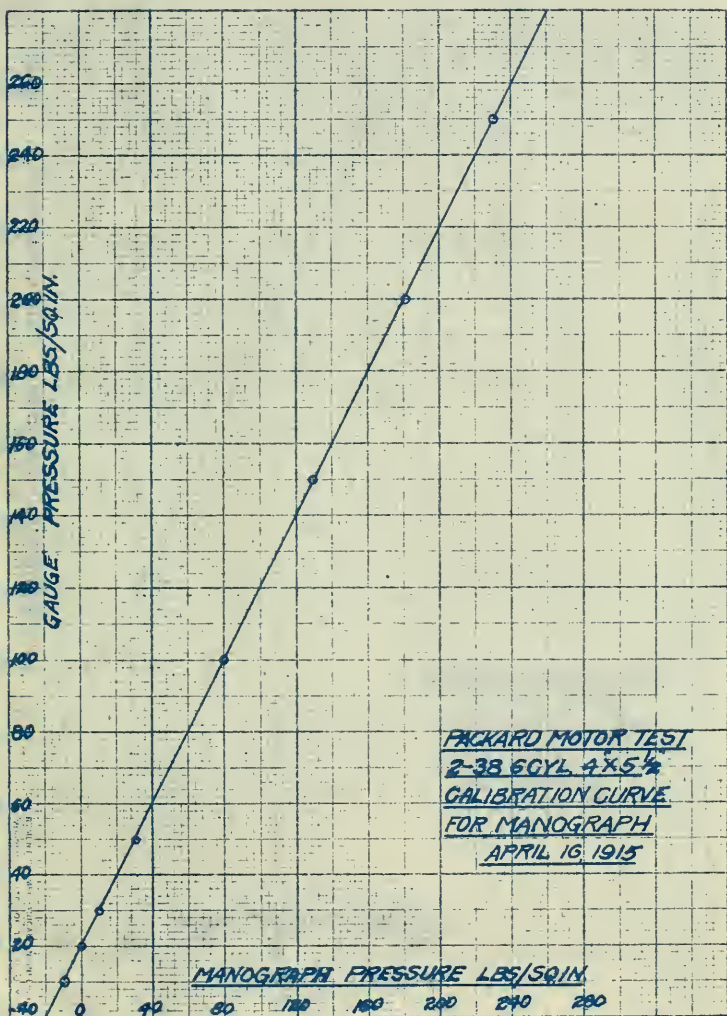
Curves.

Manograph Cards.

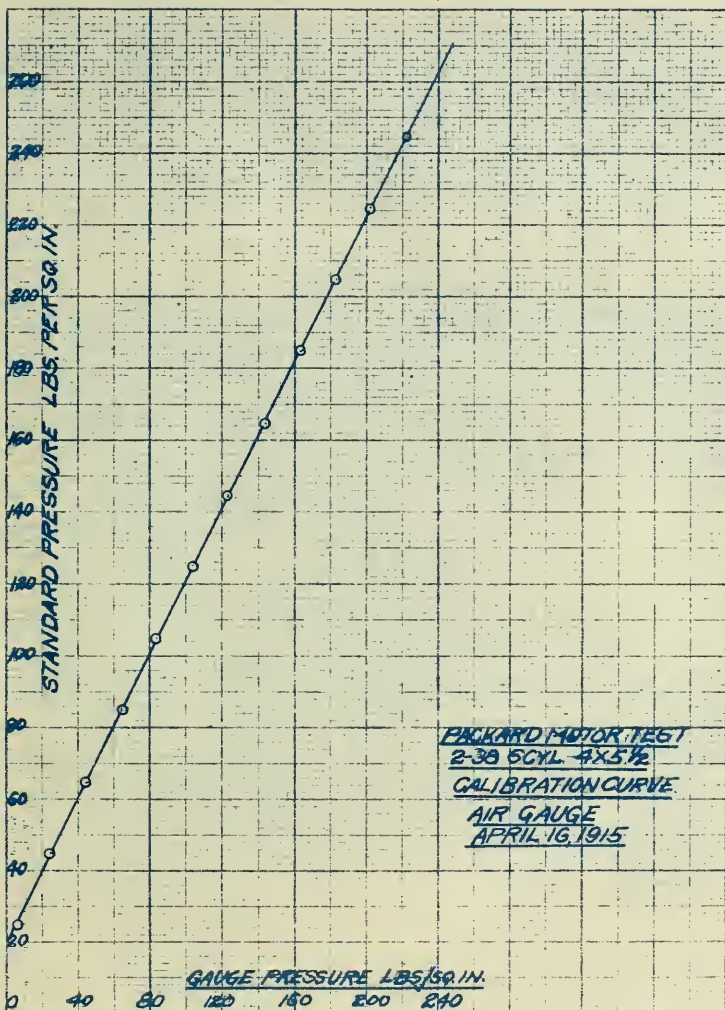
THE STATE OF NEW YORK, COUNTY OF ALBANY, ss. I, the undersigned, Clerk of the said County, do hereby certify that the within and foregoing is a true and correct copy of the original of the same as the same appears from the records of the said County.

1. The first step is to identify the problem. This involves understanding the situation and the goals that need to be achieved.

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Calibration Card

Pressure

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30
50
65
100
150
203
243





Calibration Card

Pressure

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243

Index to Data Sheets
and Curves.

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PACKARD MOTOR TEST

OBJECT: POWER & ECONOMY

SUCTION - WIDE OPEN THROTTLE

TEST NO. 1

MOTOR 2-38"

6 CYL. 4 X 5 1/2"

NO. 53554

DATE: APRIL 7, 1915

BAR 29.40 IN. HG.

TEMP 65 DEG. F.

GASOLINE 60° B at 67° F.

RUN NO.	RPM	TORQ	BHP	F.H.P.	B.H.P. + F.H.P.	M.E.	M.E. NET	TEMP COOL. WATER DEG. F.		PRESSURES IN. HG.		JACKET WATER		GAS CONSUMPTION		THER. EFF. %	HEAT ABS. WATER %	HEAT EXH. RAD. ETC. %	POS. SPARK ADV.
								INLET	OUTLET	INTAKE	EXHAUST	LBS. PER H.R.	BRZ. PER H.R.	LBS. PER H.R.	BRZ. PER H.R.				
1	664	173	288	4.0	32.8	87.7	82.8	111	120	1/2	—	11250	101250	22.9	824	168	26.1	57.1	24
2	992	175	435	8.5	52.0	83.7	83.8	118	126	1 1/8	—	15250	122000	35.6	819	163	18.1	65.6	28
3	1361	157.5	536	14.9	68.5	78.2	75.3	115	122	1 5/8	—	20700	145000	39.3	792	18.2	19.5	62.3	36
4	1513	156.5	593	17.5	76.8	77.2	74.8	110	117	1 3/4	—	21200	143400	54.2	746	16.4	16.1	67.5	39
5	1747	139	60.7	23.0	83.7	72.5	66.4	109	117	2 1/8	—	22000	176000	48.3	797	16.3	18.5	65.2	40
6	1940	119	57.7	28.0	85.7	67.3	56.8	109	116	2 1/4	—	22000	154000	50.0	867	14.2	15.0	70.8	40

PACKARD MOTOR TEST

OBJECT: POWER

SUCTION - WIDE OPEN THROTTLE

TEST NO. 15

MOTOR 2-38
GCYL. 4 X 5 1/2"
NO. 53554

DATE: APRIL 16, 1915
BAR 29.48 IN. HG.
TEMP 68 DEG. F.
GASOLINE 60° B at 67° F.

RUN NO	RPM	TORR	B.H.P.	F.H.P.	B.M.P. + F.H.P.	M.E.	M.F.P. NET	TEMP COOL. WATER DEG. F.		JACKET WATER		PRESSURE'S IN HG.		POS. SPARK ADV.
								INLET	OUTLET	LES. PSI H.R.	LES. BTU ABS. H.R.	INTAKE	EXH.	
1	641	174	27.9	4.0	31.9	87.5	83.2	94	101	11000	77000	1/2	3/8	30
2	809	175	35.8	6.0	41.8	85.7	84.7	99.5	109.5	13000	130000	13/16	1 1/16	32.5
3	1236	162	50	12.5	62.5	80	77.4	109.5	116.5	18150	121000	1 3/8	1	34
4	1400	162	56.8	15.5	72.3	78.6	77.5	94	102	20200	161600	1 3/8	1 3/8	42
5	1204	167.5	50.5	12.0	62.5	80.7	80.1	92	101	17800	160200	1 5/8	1 1/8	39
6	1554	159.5	61.9	18.5	80.4	77	76.1	102	108	21500	129000	1 5/8	2 3/16	43
7	1620	153.3	62.1	20.0	82.1	75.6	73.2	108	116	21800	174400	1 7/8	2 1/16	45
8	1758	142	62.5	23.0	85.5	73	67.8	117	122.5	22000	176000	1 5/8	2 3/4	45
9	1842	139.5	62	25.1	87.0	71.3	64.3	118	125	22000	220000	1 7/8	2 1/8	45
10	1940	129.5	62.8	28.0	90.8	64.2	61.9	97	106	22000	198000	1 7/8	3 3/8	45

PACKARD MOTOR TEST

OBJECT: POWER & ECONOMY

SUCTION 2" HG.

TEST NO. 2

MOTOR 2-38

6 CYL 4" X 5 1/2"

NO. 53554

DATE: APRIL 9, 1915

BAR. 29.40 IN. HG.

TEMP. 65 DEG. F.

GASOLINE 60° B at 67°F.

RUN NO.	R.P.M.	TORQ.	B.H.P.	F.H.P.	B.H.P. + F.H.P.	M.E.	MEP NET	TEMP. COOLING WATER DEG. F.		PRESSURES IN. HG.		JACKET WATER		GAS CONSUMPTION		THER. EFF. %	HEAT ABS. IN. JACKET. WATER. %	HEAT EXH. RADI. ETC. %	POS. SPARK ADV.
								INLET	OUTLET	INTAKE	EXHAUST	LBS. PER MIN.	G.T.U. ABS. PER MIN.	LBS. PER MIN.	B.H.P.				
1	628	169	26.5	4.0	30.5	86.8	80.6	106	113.5	2	1 1/2	10900	81750	18.61	.703	19.0	23.1	57.9	28°
2	818	170.5	34.85	5.5	40.36	86.5	81.5	120	130.3	2	1 1/6	13200	132000	23.44	.67	19.9	29.6	50.6	32°
3	1418	158.5	56.2	16.5	72.7	77.3	75.7	118	127.3	2	1 1/2	20500	184500	40.42	.718	18.66	24.1	57.24	34°
4	1694	148.5	62.9	23.0	85.9	73.2	70.9	104	113.3	2	3	22000	198000	46.8	.744	18.0	22.25	59.8	40°
5																			
6																			
7																			
8																			
9																			

TEST NO. 3

MOTOR 2-38"
6 CYL. 4" X 5 1/2"
NO. 53554

DATE: APRIL 9, 1915
BAR. 29.40 IN. HG.
TEMP. 65 DEG. F.
GASOLINE 60° BAY 67° F.

RUN NO.	R.P.M.	TORQ.	B.H.P.	F.H.P.	B.H.P. + F.H.P.	M.E.	M.E.P. NET	TEMP. COOL.WATER DEG. F.		PRESSURES IN. HG.		JACKET WATER		GAS CONSUMPTION		THER. EFF. %	HEAT ABS. IN JACKET EXH. WATER AND EXH. %	HEAT ABS. IN SPARK ADK %	
								INLET	OUTLET	INTAKE	EXHAUST	LBS. PER H.R.	G.T.U. ABS. PER H.R.	LBS. PER H.R.	LBS. PER B.H.P.H.R.				
1	672	162.5	273	50	32.3	84.5	77.6	873	973	3	1/2	11350	113500	14.8	.52	18.8	42.1	39.1	32
2	894	162	36.4	80	44.4	82	77.8	113	120.2	3	1 3/16	14100	98700	23.8	.654	20.5	21.7	57.8	34
3	1228	155	47.6	140	61.6	77.3	74	118.5	127.5	3	1 1/2	18150	63350	33.6	.707	18.95	25.5	55.5	38
4	1526	149	56.8	20.5	77.3	73.5	71.2	115.3	124.8	3	1 7/8	21400	203300	38.2	.672	19.9	27.9	52.2	40
5	1739	140.5	61.0	25.5	86.5	70.6	67	108	117	3	2 7/8	22000	198000	43.2	.708	18.9	24.1	57.0	40

PACKARD MOTOR TEST

OBJECT: POWER & ECONOMY

SUCTION 16" Hg.

TEST NC. 7

MOTOR 2-38

6 CYL. 4" X 5 1/2"

NO. 53554

DATE: APRIL 9, 1915

BAR. 29.40 IN. Hg.

TEMP. 65° DEG. F.

GASOLINE 60° Bat 67° F.

RUN NO	R.P.M.	TORQ	B.H.P.	F.H.P.	M.E.	M.E.P. NET	TEMP. COOL. WATER DEG. F.		PRESSURES IN. Hg.		JACKET WATER		GAS CONSUMPTION		THER EFF. %	HEAT IN. JACKET WATER %	HEAT EXH. RADI. ETC. %	POS. SPARK ADV.
							INLET	OUTLET	INTAKE	EXHAUST	LBS. PER HR.	RTA. ABS. PER HR.	LBS. PER HR.	PER B.H.P.				
1	344	47.5	1.08	2.5	6.58	62	113	120	16	3/32	8000	56000	9.72	2.43	5.6	30.2	64.2	40
2	826	45.5	9.39	9.0	18.4	51	101	106	16	1/8	13350	66750	11.78	1.25	10.7	29.8	59.6	40
3	1033	38.5	10.13	13.5	23.6	42.8	114	119	16	1/8	16000	90000	14.04	1.37	9.7	33.7	56.6	40
4	1219	32.5	9.9	17.0	26.9	36.8	116	122	16	3/16	18000	108000	15.84	1.60	8.4	35.8	55.8	40
5	1514	19.3	7.3	24.0	31.3	23.3	114	120	16	1/2	21200	127200	20.66	2.83	4.7	32.4	52.8	40
6	1666	10.5	4.37	27.5	31.87	13.7	115	121	16	9/16	21900	131400	20.16	4.38	2.9	34.2	62.9	40

PACKARD MOTOR TEST

OBJECT: FRICTION H.P. DATE 4-14-15

SUCTION-WIDE OPEN THROTTLE TEMP 65 °F

TEST NO. 8

BAR. 29.4 HG

RUN NO.	R.P.M.	TORQUE	F.H.P.	SUCTION INTAKE IN. HG.	TEMP. COOLING WATER DEG. F.	
					INLET	OUTLET
1	263	13.5	.888	3/16	123	125
2	351	14.8	1.30	1/4	123	124
3	470	17.5	2.06	3/8	118	119
4	570	21.0	2.99	3/8	116	117
5	694	25.25	4.38	7/16	116	117
6	810	29.3	5.93	1/2	116	117
7	974	36.0	8.76	5/8	116	117

PACKARD MOTOR TEST

OBJECT: FRICTION H.P.

DATE 4-14-15

SUCTION-

TEMP. 65°F

TEST NO. 9

BAR. 29.4 HG.

RUN NO.	R.P.M.	TORQUE	F.H.P.	SUCTION INTAKE IN. HG.	TEMP. COOLING WATER DEG. F.	
					INLET	OUTLET
1	260	16.5	1.07	2	115	116
2	386	18.0	1.66	2	114	115
3	449	19.5	2.19	2	114	115
4	565	22.5	3.18	2	114	115
5	663	25.3	4.18	2	113	114
6	773	28.5	5.51	2	113	114
7	912	34.0	7.75	2	113	115
8	980	37.0	9.06	2	114	115
9	1008	38.0	9.43	2	115	117

PACKARD MOTOR TEST

OBJECT: FRICTION H.P.

DATE: 4-14-15

SUCTION - 3"

TEMP. 65 °F

TEST NO. 10

BAR. 29.4" Hg

RUN NO.	R.P.M.	TORQUE	F.H.P.	SUCTION INTAKE	TEMP. COOLING WATER DEG. F.	
					INLET	OUTLET
1	268	17.25	1.16	3	115	116
2	364	18.25	1.66	3	114	115
3	464	20.25	2.35	3	114	115
4	570	23.5	3.35	3	113	114
5	700	27.5	4.82	3	113	114
6	826	31.5	6.51	3	114	115
7	886	34.5	7.64	3	114	115
8	988	37.75	9.33	3	114	115

PACKARD MOTOR TEST

OBJECT: FRICTION H.P.

DATE 4-14-15

SUCTION - 6"

TEMP. 65 °F

TEST NO. 11

BAR. 29.4" Hg.

RUN NO.	R.P.M.	TORQUE	F.H.P.	SUCTION INTAKE IN. Hg.	TEMP. COOLING WATER DEG. F.	
					INLET	OUTLET
1	306	18.5	1.42	6	115	116
2	376	20.25	1.9	6	115	116
3	504	23.25	2.17	6	114	115
4	618	26.5	4.1	6	114	115
5	726	30.0	5.44	6	114	115
6	854	33.75	7.2	6	114	115
7	930	38.75	9.01	6	114	115

PACKARD MOTOR TEST

OBJECT: FRICTION H.P.

DATE 4-14-15

SUCTION - 10"

TEMP. 65°F.

TEST NO. 12

BAR. 29.4" HG.

RUN NO.	R.P.M.	TORQUE	F.H.P.	SUCTION INTAKE IN. HG.	TEMP. COOLING WATER DEG. F.	
					INLET	OUTLET
1	252	20.25	1.28	10	115	116
2	350	23.5	2.06	10	115	116
3	444	26.0	2.89	10	114	115
4	596	29.5	4.4	10	114	115
5	710	33.0	5.86	10	114	115
6	820	36.25	7.43	10	114	115
7	958	44.75	10.0	10	114	115

PACKARD MOTOR TEST

OBJECT: FRICTION H.P.

DATE 4-14-15

SUCTION - 14"

TEMP. 65°F.

TEST NO. 13

BAR. 29.4" HG.

RUN NO.	R.P.M.	TORQUE	F.H.P.	SUCTION INTAKE IN. HG.	TEMP. COOLING WATER DEG. F.	
					INLET	OUTLET
1	268	23.0	1.54	14	114	115
2	354	25.6	2.27	14	114	115
3	460	29.0	3.34	14	113	114
4	586	32.5	4.76	14	107	108
5	734	36.75	6.75	14	108	109
6	830	40.5	8.41	14	108	109

PACKARD MOTOR TEST

OBJECT: FRICTION H.P.

DATE 4-14-15

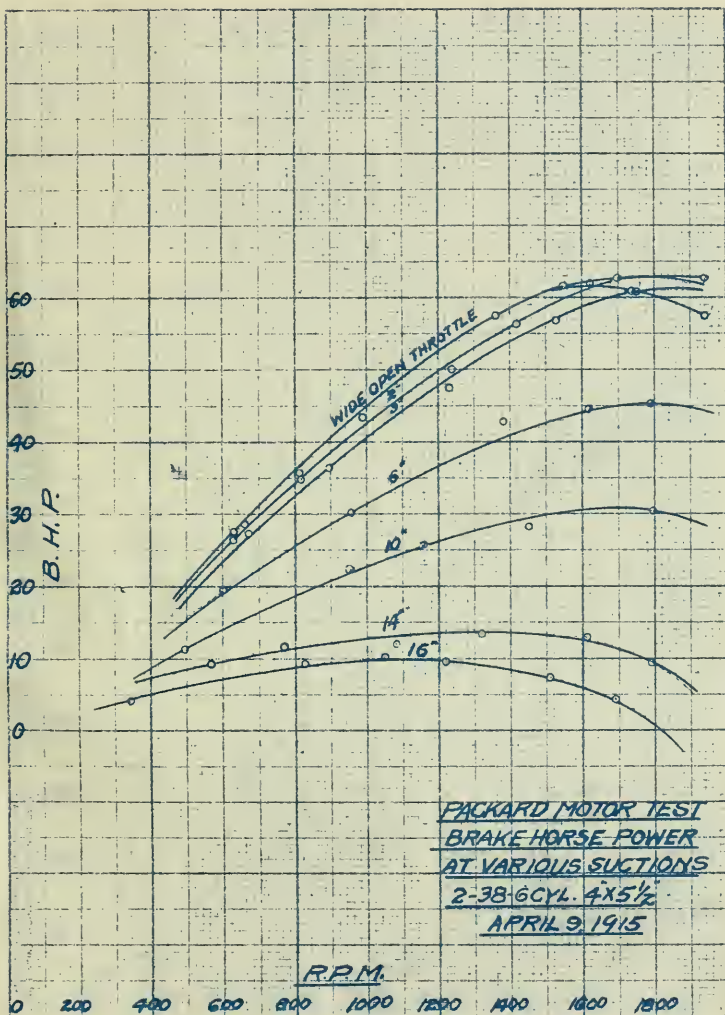
SUCTION 16"

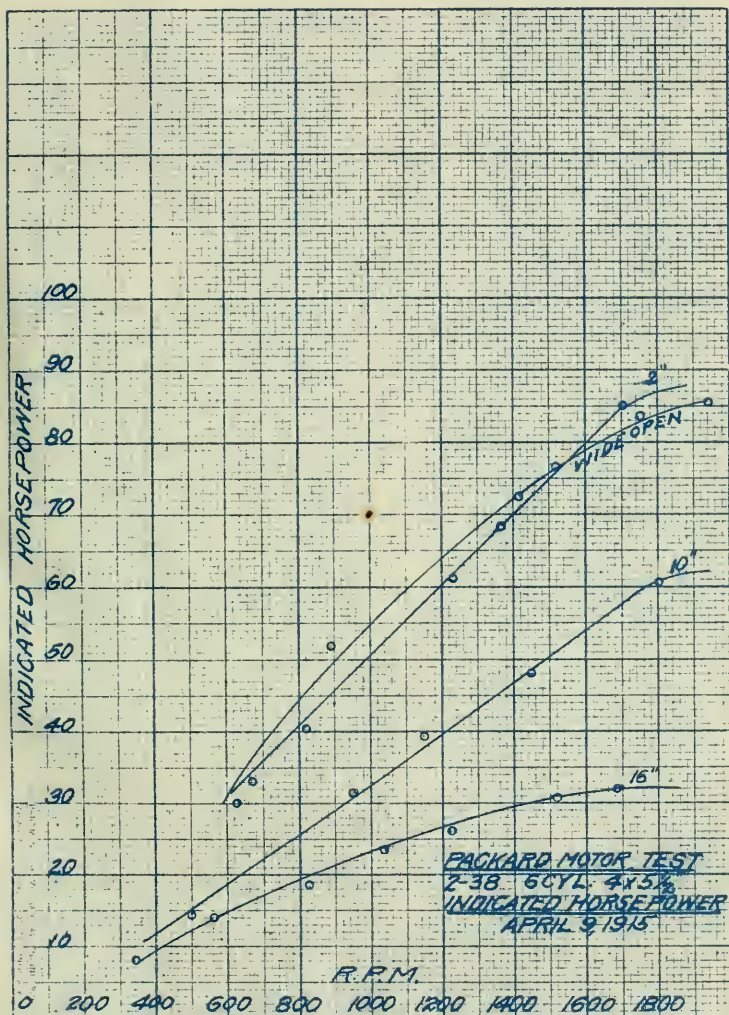
TEMP. 65°F

TEST NO. 14

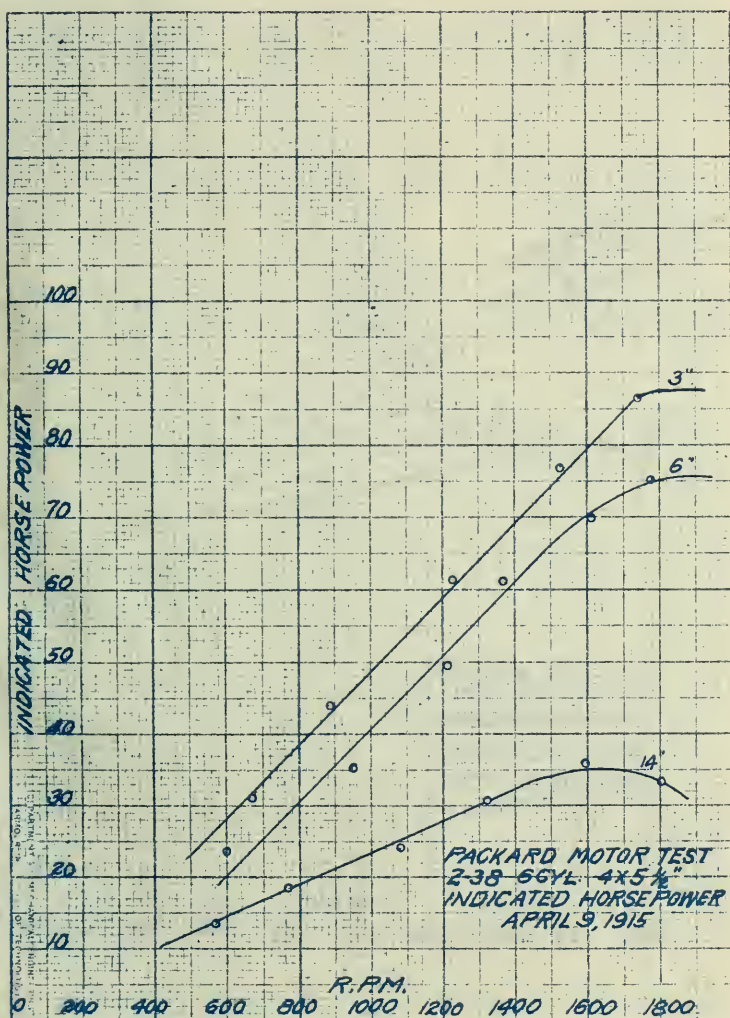
BAR. 29.4 HG.

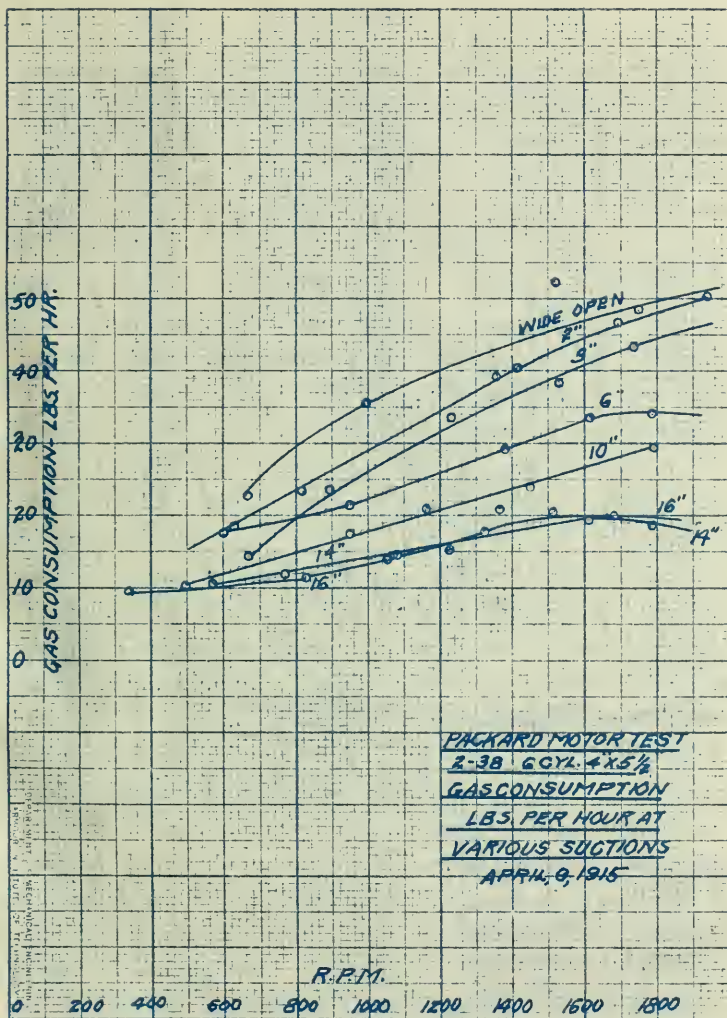
RUN NO.	R.P.M.	TORQUE	F.H.P.	SUCTION INTAKE IN. HG.	TEMP. COOLING WATER DEG. F.	
					INLET	OUTLET
1	222	24.0	1.33	16	107	108
2	340	28.25	2.4	16	108	109
3	476	31.75	3.77	16	108	109
4	616	37.75	5.81	16	108	109
5	744	41.5	7.76	16	108	109
6	854	44.5	9.5	16	108	109

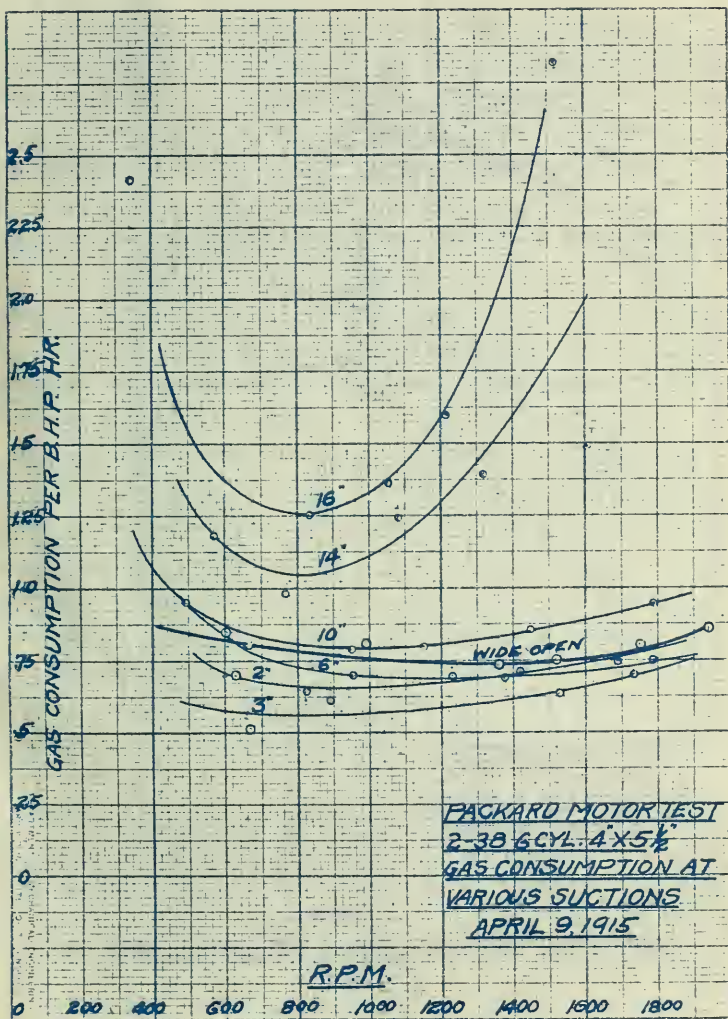


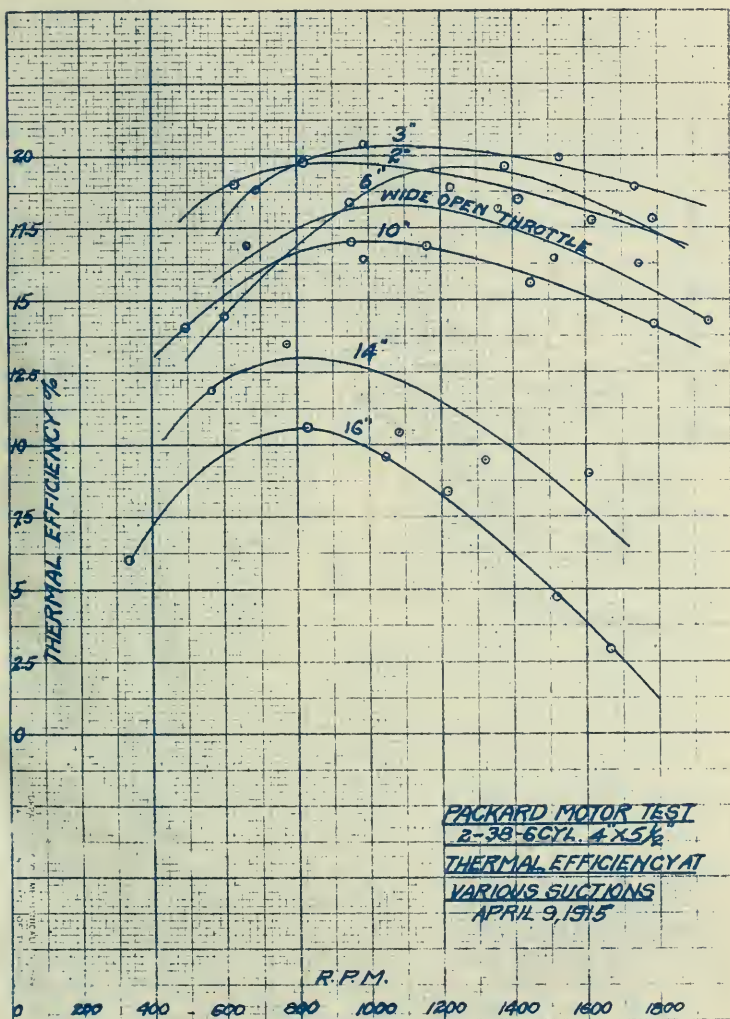


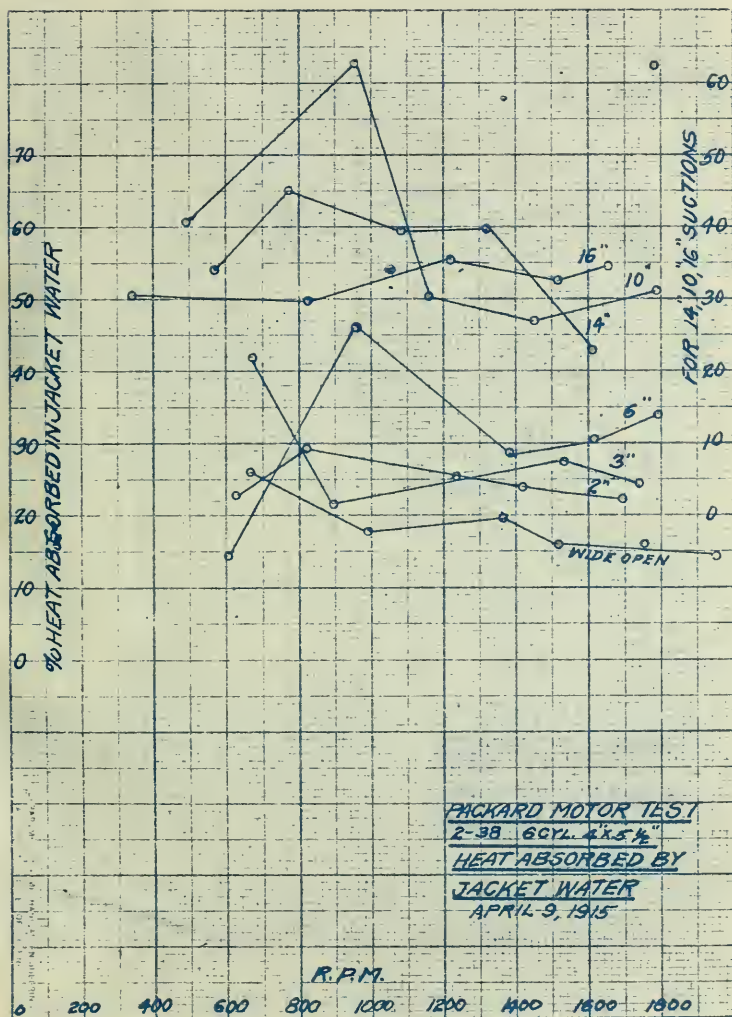


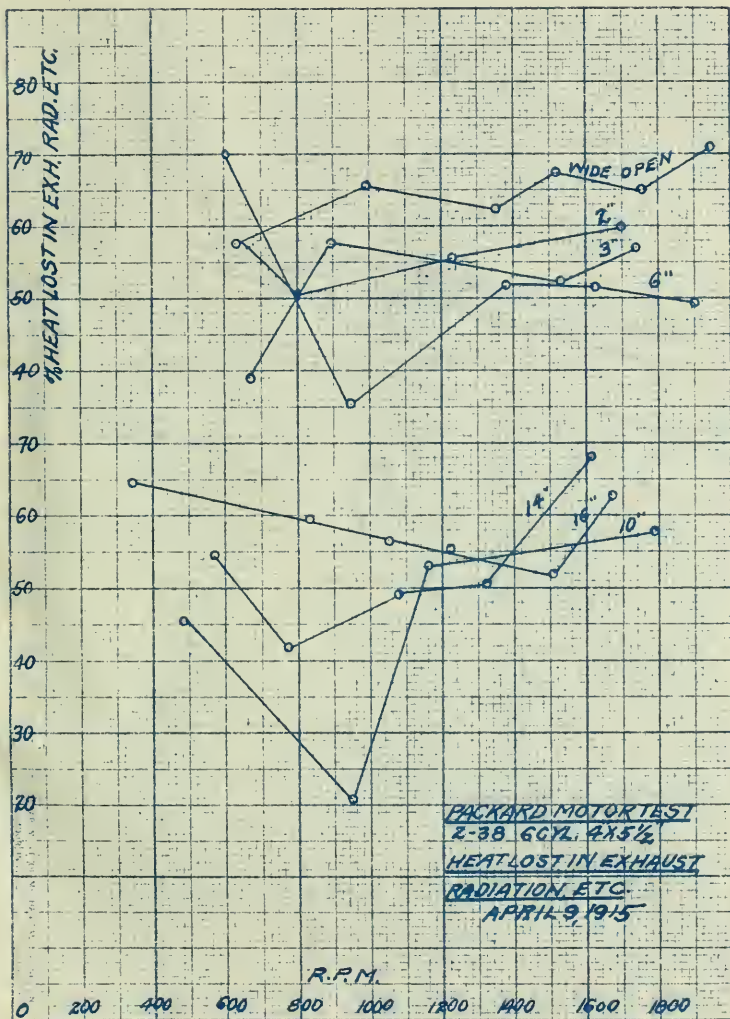


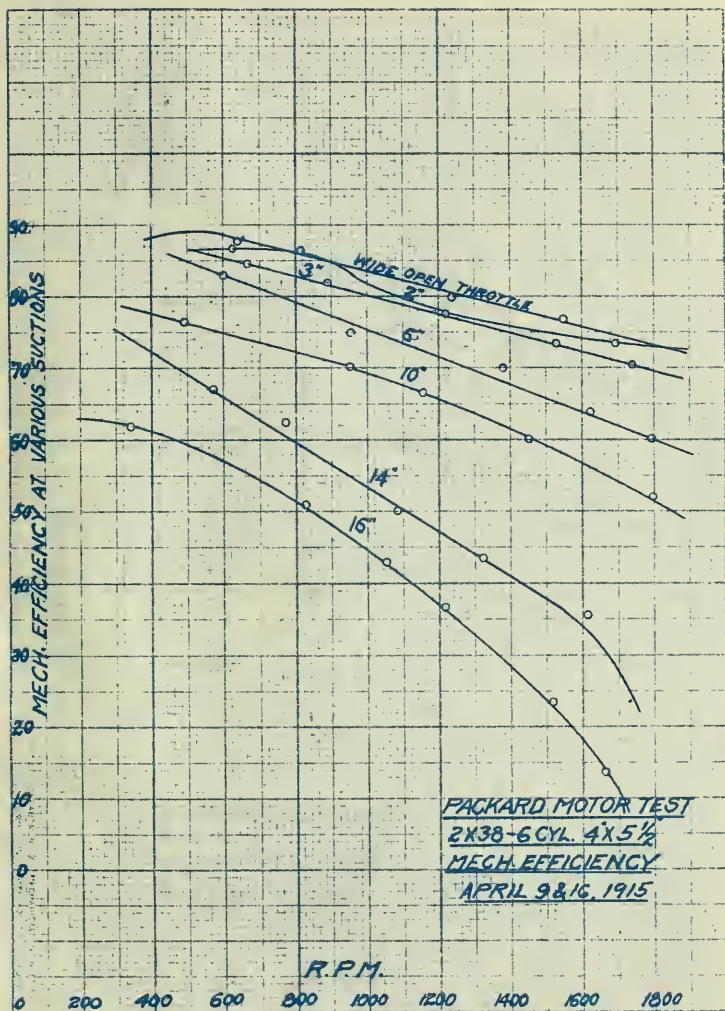




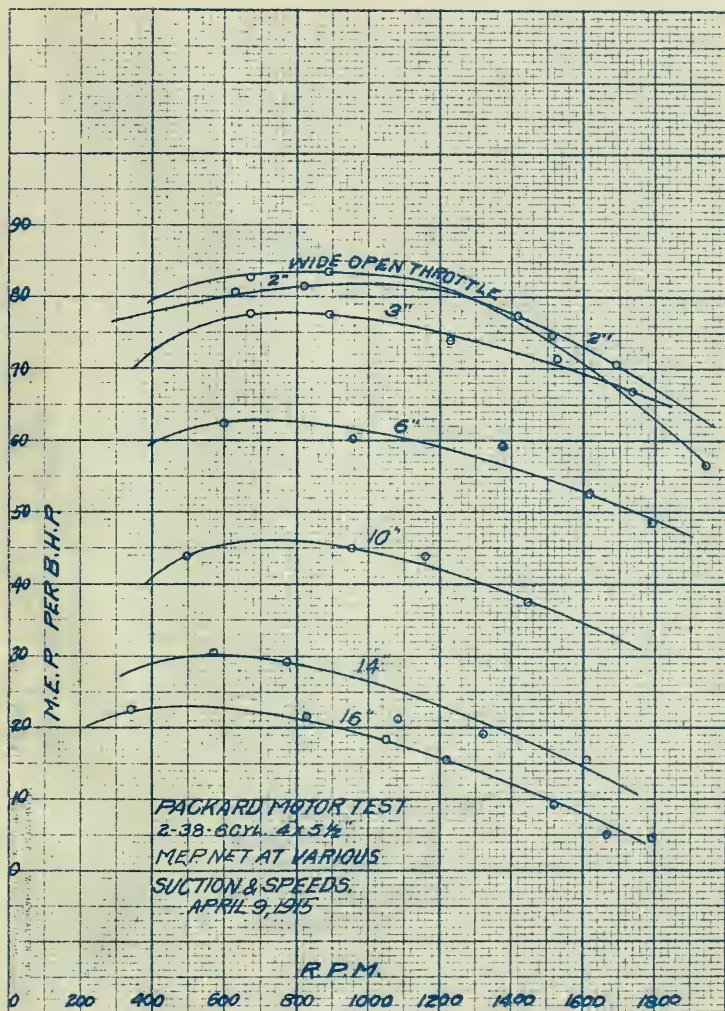


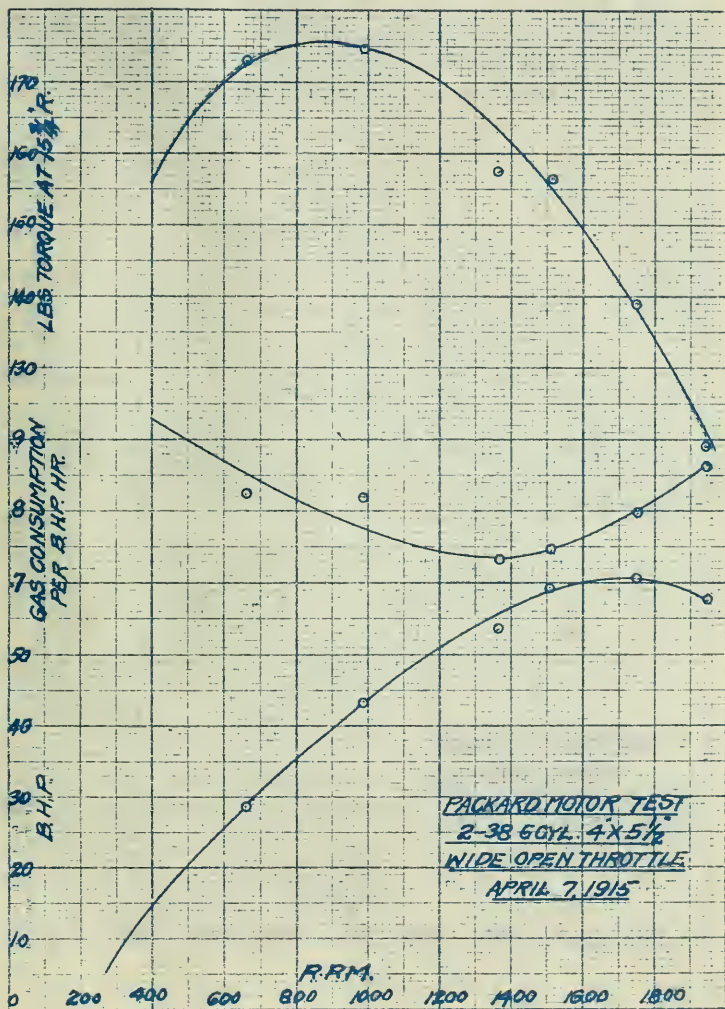


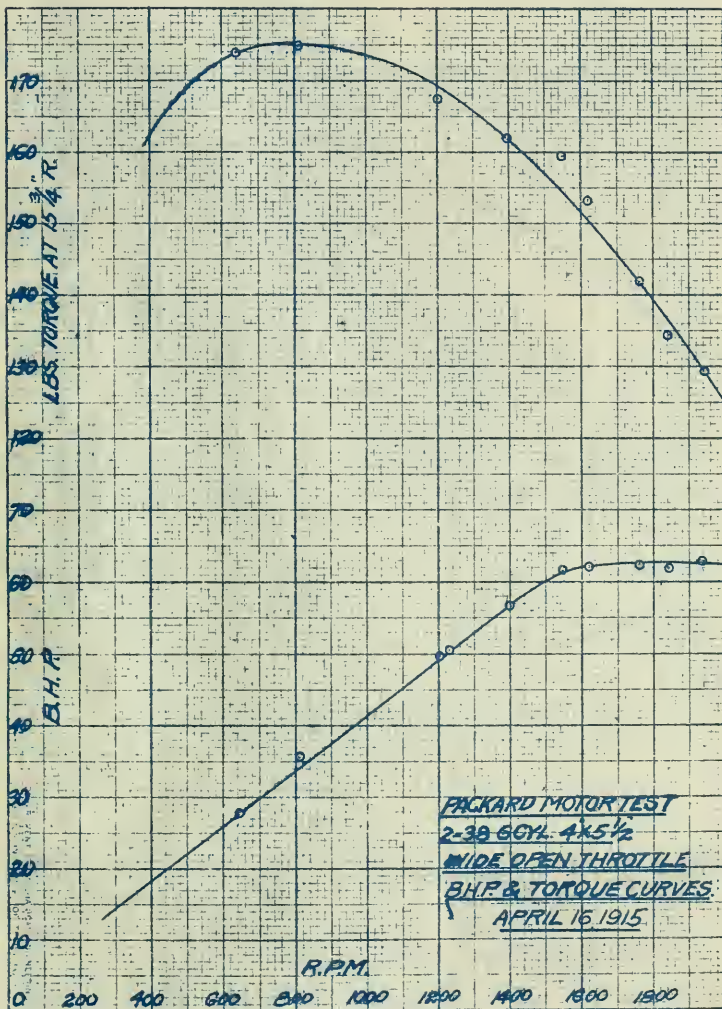




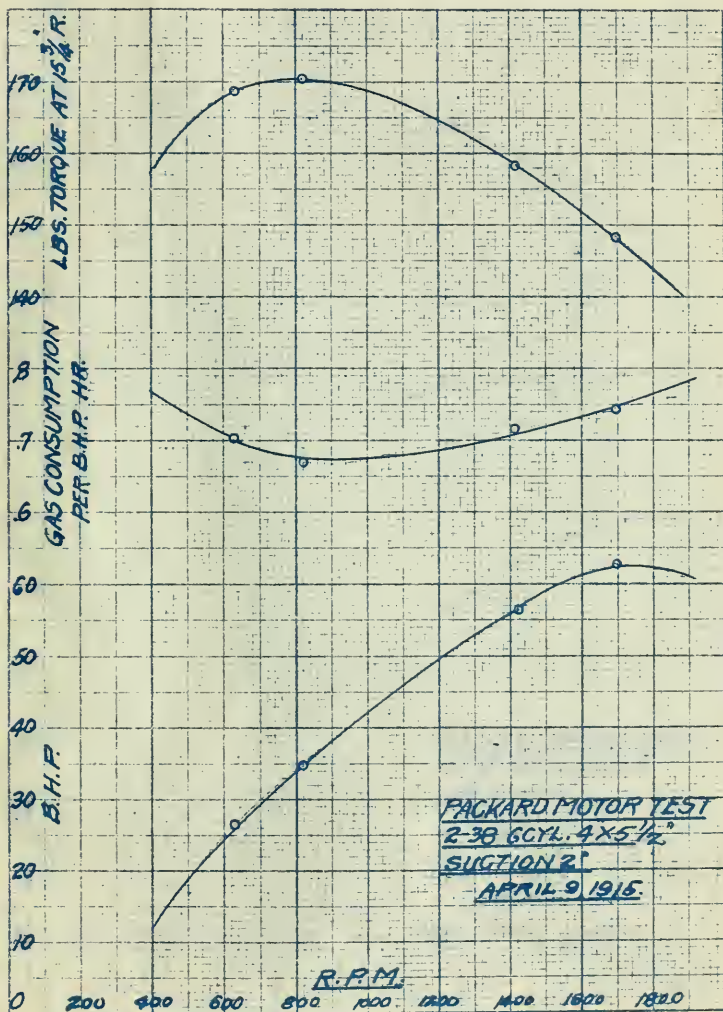






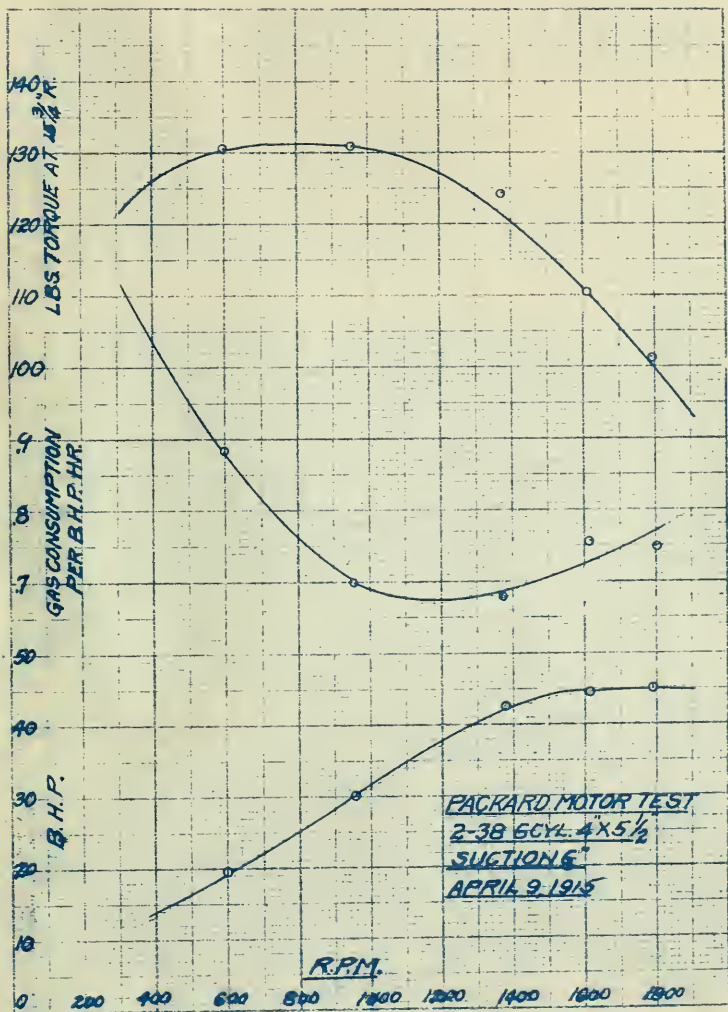


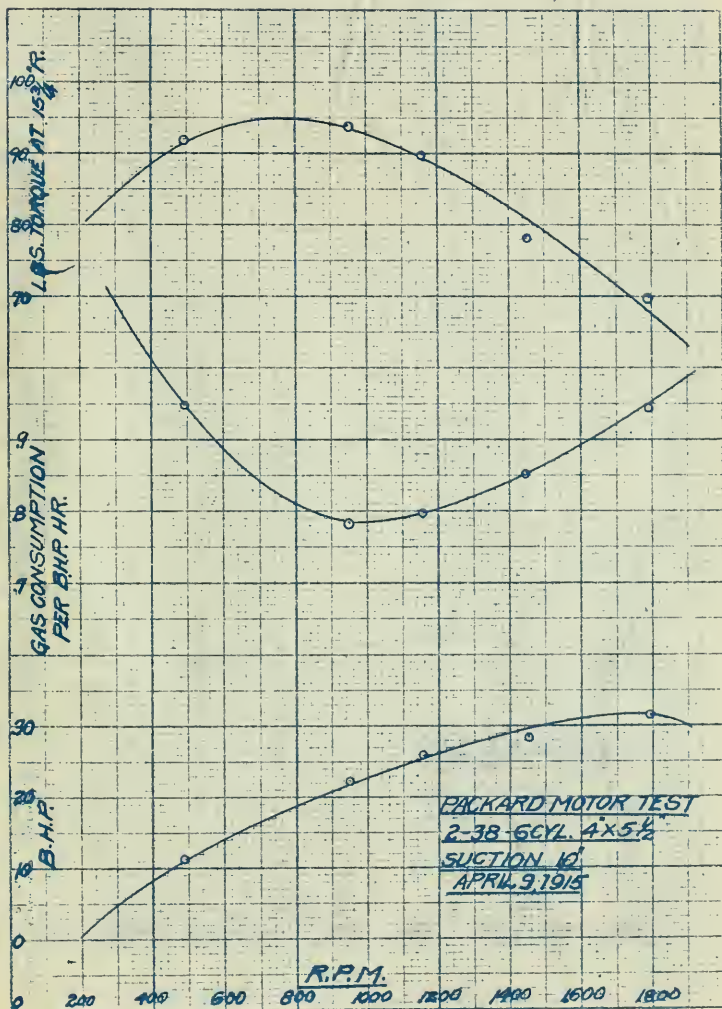


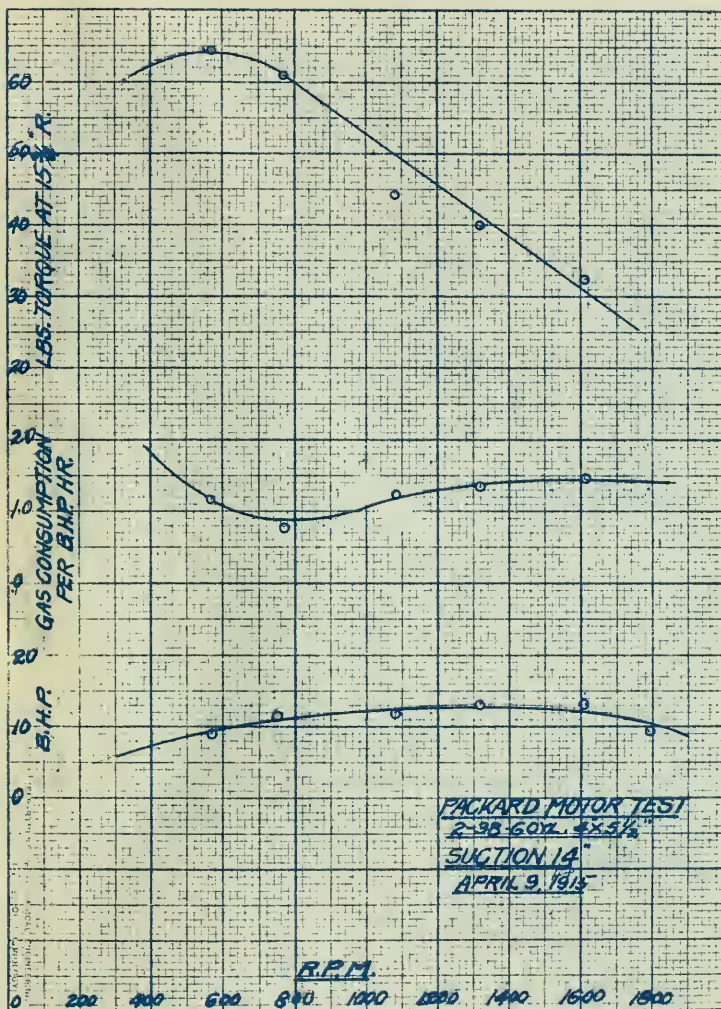




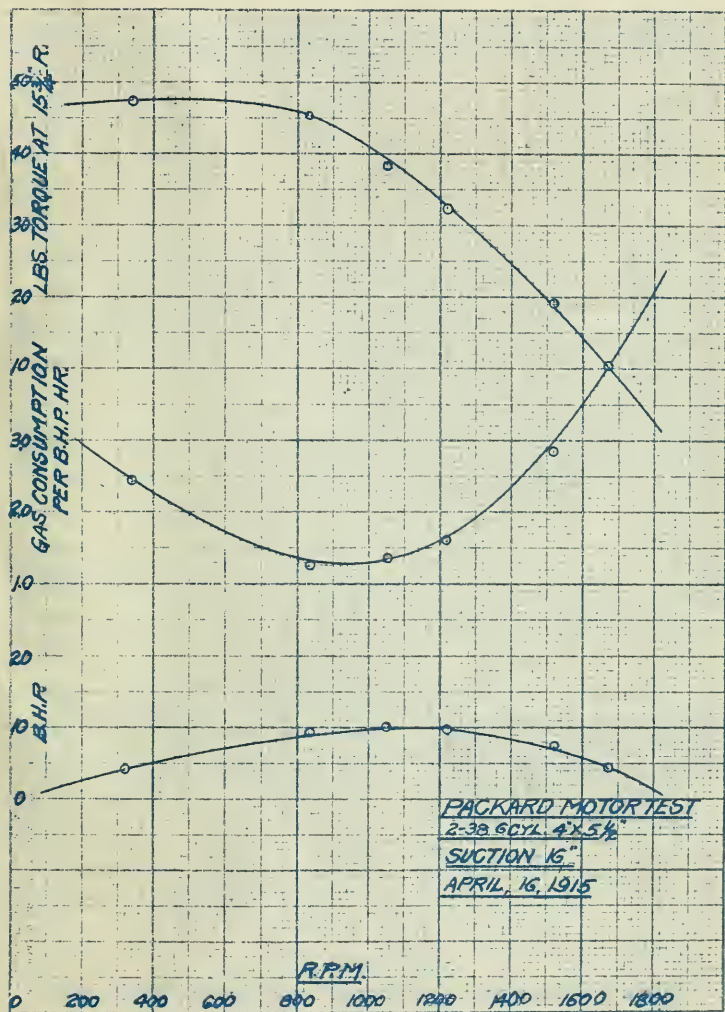
1. $\text{H}_2\text{O} + \text{CO}_2 \rightleftharpoons \text{H}_2\text{CO}_3$
 2. $\text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$
 3. $\text{HCO}_3^- \rightleftharpoons \text{CO}_3^{2-} + \text{H}^+$
 4. $\text{H}^+ + \text{OH}^- \rightleftharpoons \text{H}_2\text{O}$
 5. $\text{H}_2\text{O} \rightleftharpoons \text{H}^+ + \text{OH}^-$

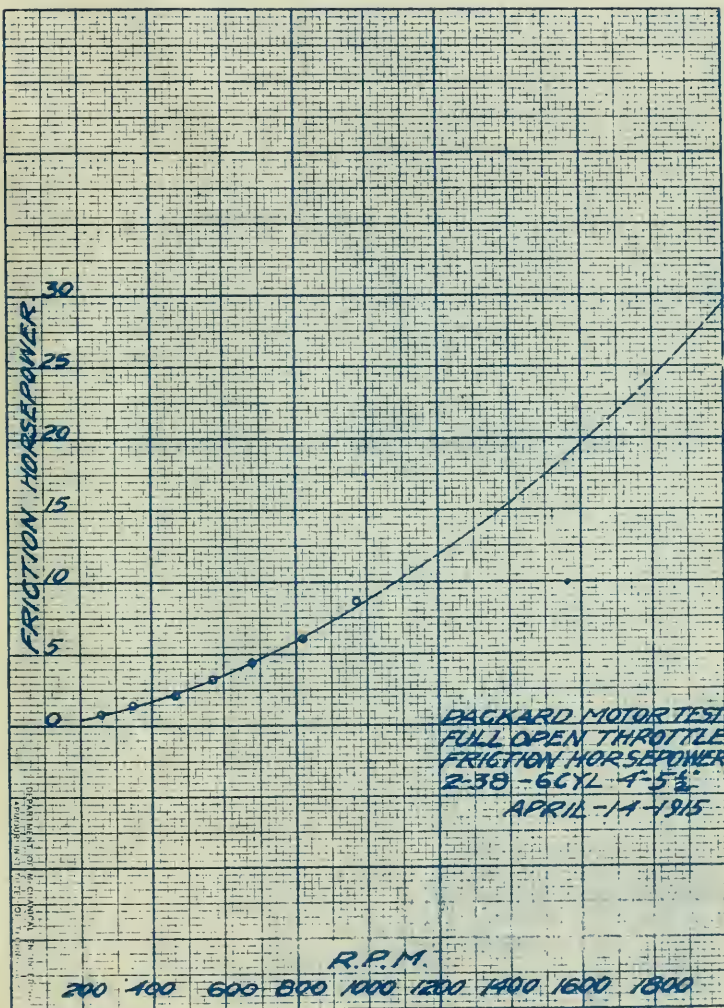


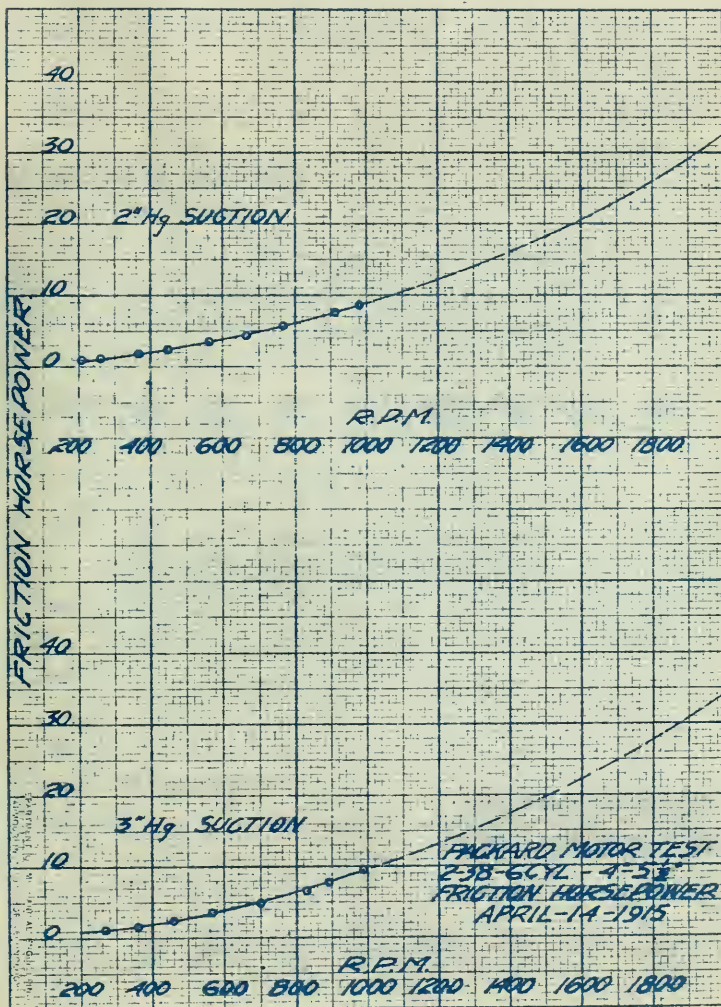


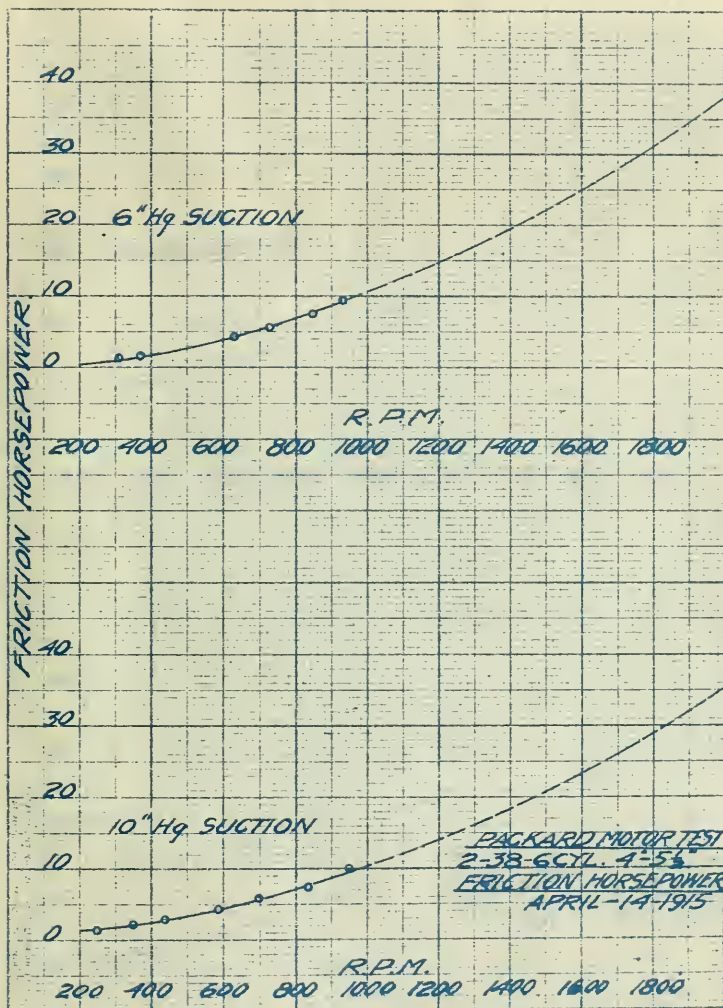


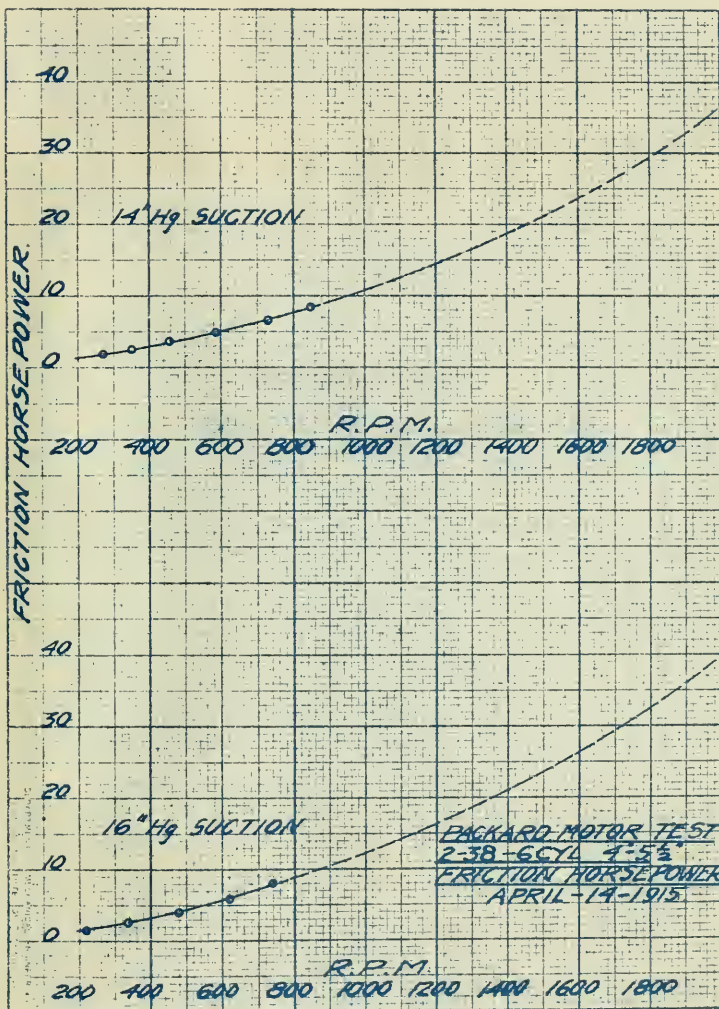












Monograph Cards
for
Different Speeds, Loads, and
Suction Pressures.

Suction 16 inches.

R. P. M. 666

Torque 44.7

Spark 40

B. H. P. 7.45



Suction	16 inches.
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R. P. M.	890
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Torque	31.0
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Spark	40
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B. H. P.	6.9
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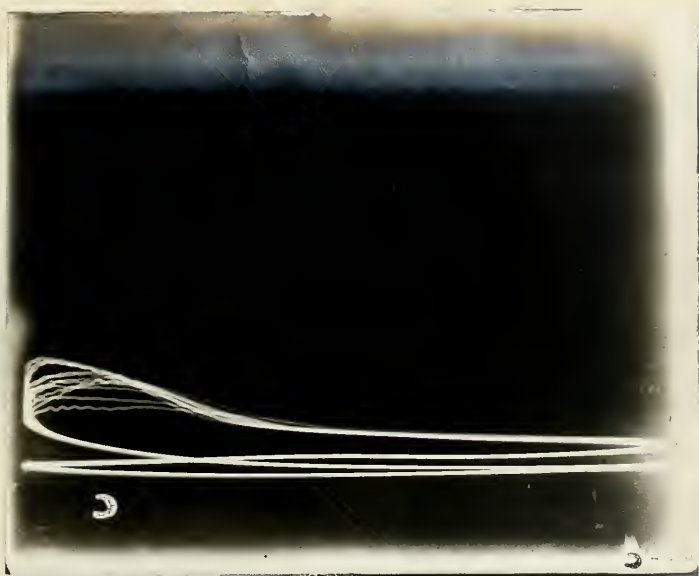
Suction 16 inches

R. P. M. 16.8

Torque 12

Spark 40

B. H. P. 4.25



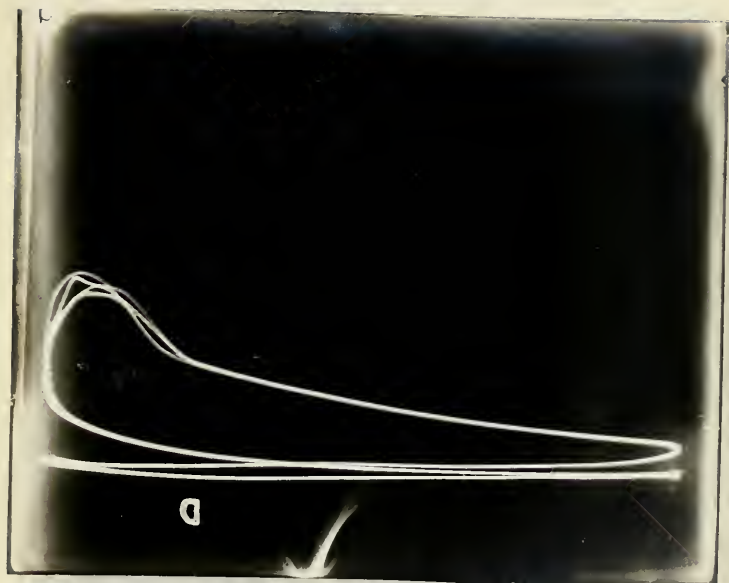
Suction 14 inches.

R. P. M. 670

Torque 63

Spark 40

B. H. P. 10.55



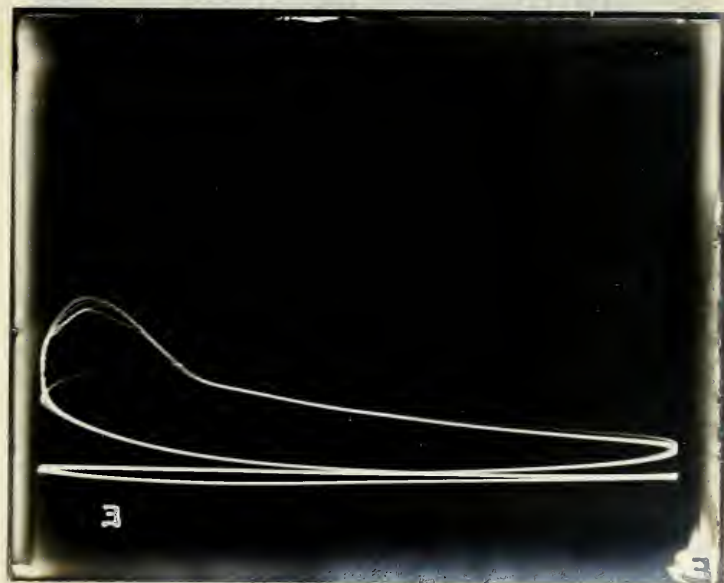
Suction	14 inches
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R. P. M.	884
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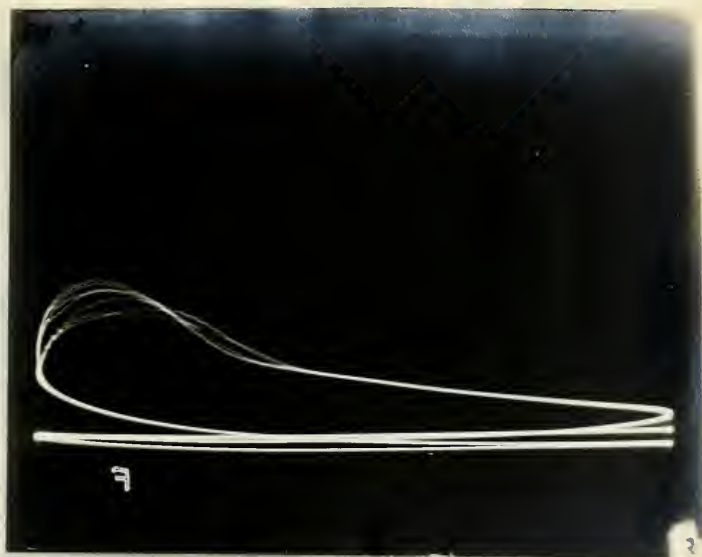
Torque	63.5
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Spark	40
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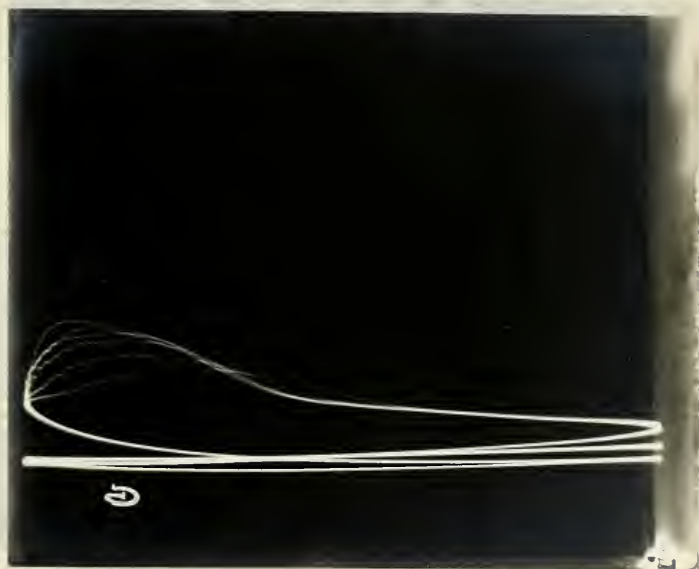
B. H. P.	14.0
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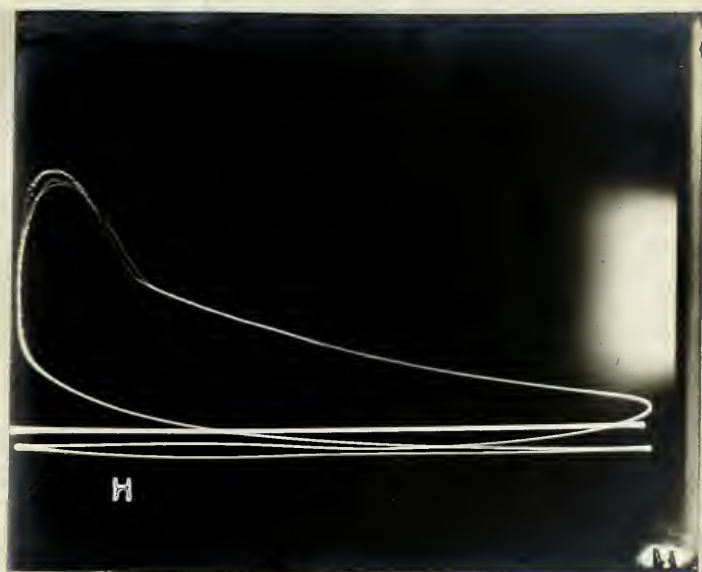
Suction	14 inches
R. P. M.	1098
Torque	54.0
Spark	40
B. H. P.	14.85



Suction	14 inches
R. P. M.	1522
Torque	45
Spark	40
B. H. P.	16.75



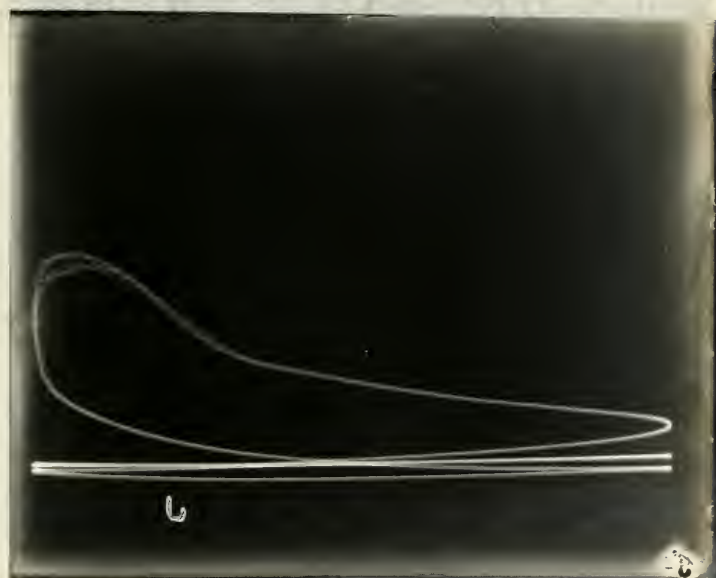
Suction	10 inches
R. P. M.	724
Torque	100
Spark	40
B. H. P.	18.1



Suction	10 inches
R. P. M.	1000
Torque	99
Spark	40
B. H. P.	24.8

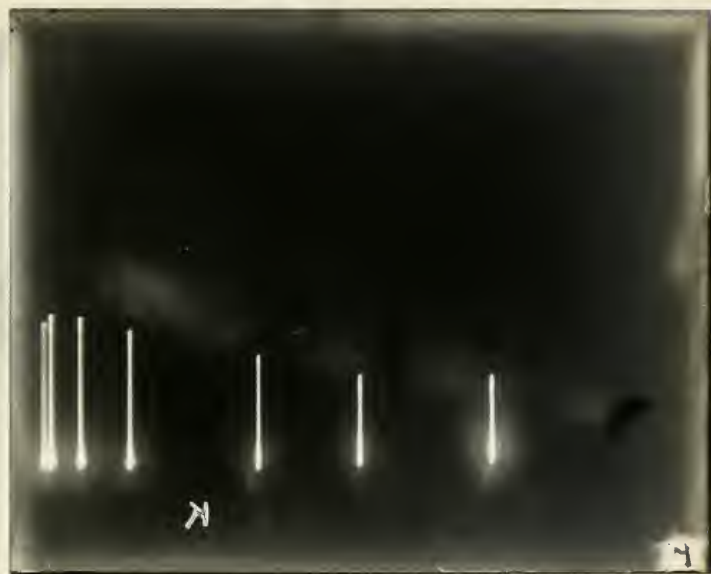


Suction	10 inches
R. P. M.	1650
Torque	31
Spark	40
B. H. P.	12.8



Compression Card.

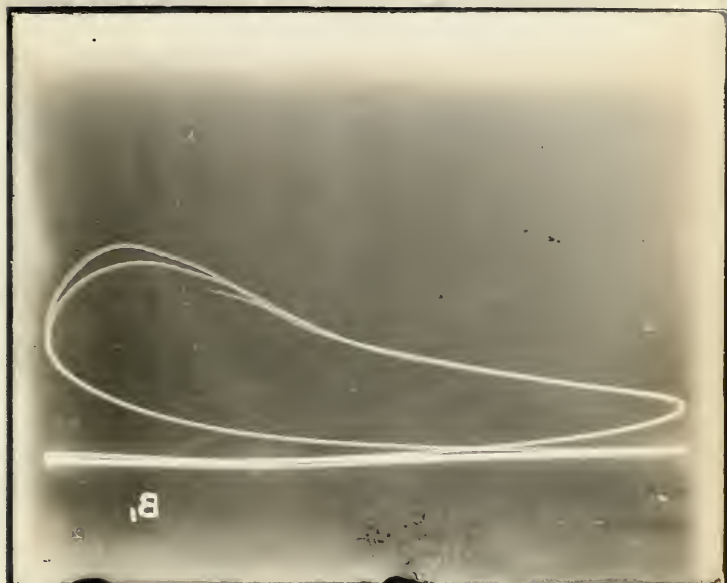
R.P.M.	Suction.
620	$1/2$
850	$7/8$
1025	$1-1/8$
1225	$1-3/8$
1475	$1-5/8$
1925	$2-1/8$
2000	$2-1/4$



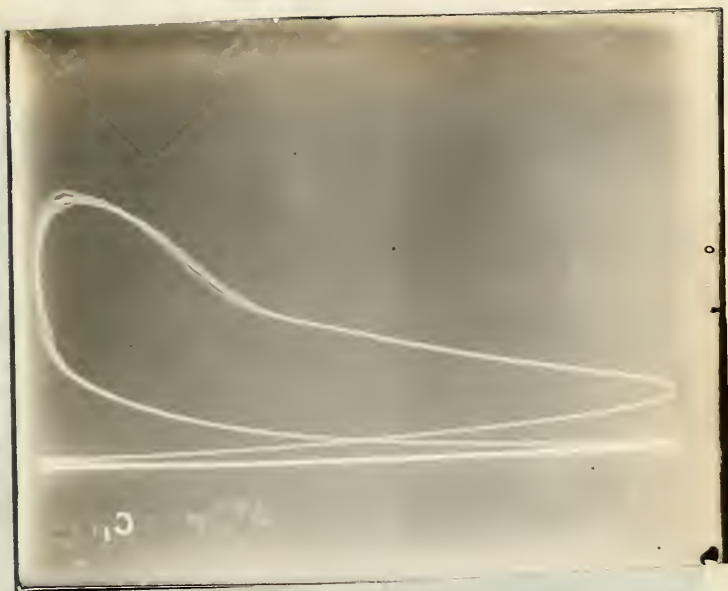
Suction	6 inches
R. P. M.	682
Torque	126.5
Spark	34
B. H. P.	21.6



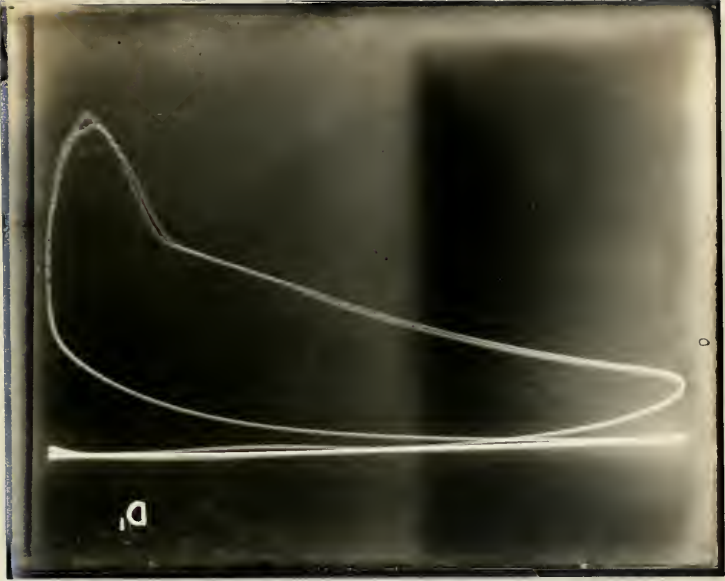
Suction	6 inches
R. P. M.	1064
Torque	123.0
Spark	40
B. H. P.	32.8



Suction	6 inches.
R. P. M.	1508
Torque	112
Spark	40
B. H. P.	42.3



Suction	3 inches.
R. P. M.	692.
Torque	158
Spark	32
B. H. P.	27.3



Suction	3 inches
R. P. M.	1178.
Torque	157
Spark	38
B. H. P.	46.1



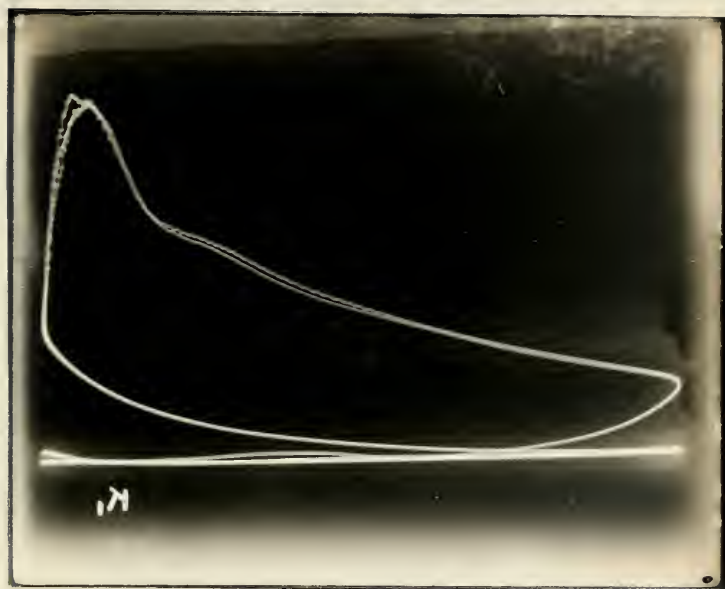
71

Suction	3 inches
R. P. M.	1572
Torque	144.5
Spark	40
B. H. P.	56.8



Suction - Wide Open Throttle.

R. P. M.	584
Torque	160
Spark	25
B. H. P.	23.4



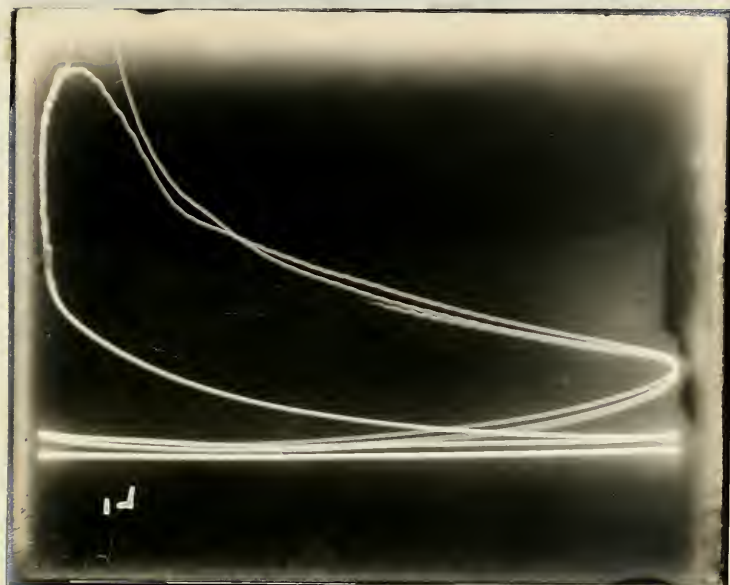
Suction - Wide Open Throttle.

R. P. M.	584
Torque	160
Spark	25
B. H. P.	23.4



Suction - Wide Open Throttle

R. P. M.	1064.
Torque	175.
Spark	32
B. H. P.	46.5



Suction 2 inches. Wide Open Throttle

R. P. M. 1534

Torque 157

Spark 40

B. H. P. 60.2



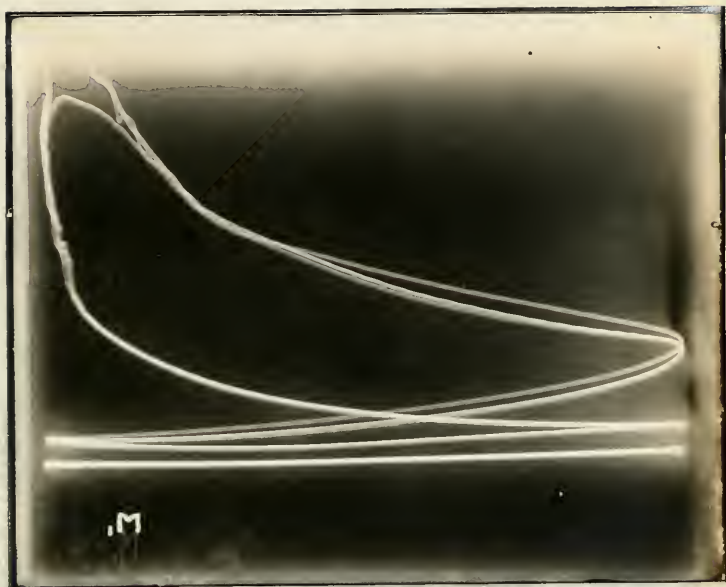
Suction 2 inches. Wide open Throttle.

R. P. M. 1534

Torque 157

Spark 40

B. H. P. 60.2



Compression Card

Suction 16 inches.

R. P. M.

540
690
860
1050
1175
1176



Compression Card

Suction 14 inches.

R. P. M.

490
650
850
1050
1225
1375
1550
1700
1840



Compression Card

Suction 10 inches

R. P. M.

555
650
820
975
1175
1350
1500
1650
1875



Compression Card

Suction 6 inches.

R. P. M.

560
740
925
1075
1250
1375
1500
1700
1800



Compression Card.

Suction 3 inches.

R. P. M.

520
690
900
1050
1225
1375
1550
1750
1850

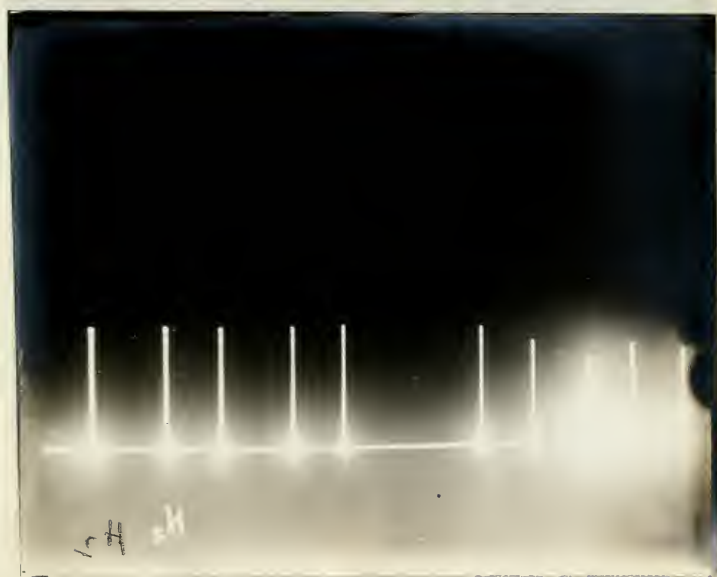


Compression Card

Suction 2 inches.

R. P. M.

515
700
850
1000
1125
1275
1450
1600
1700
1900



Compression Card

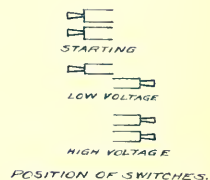
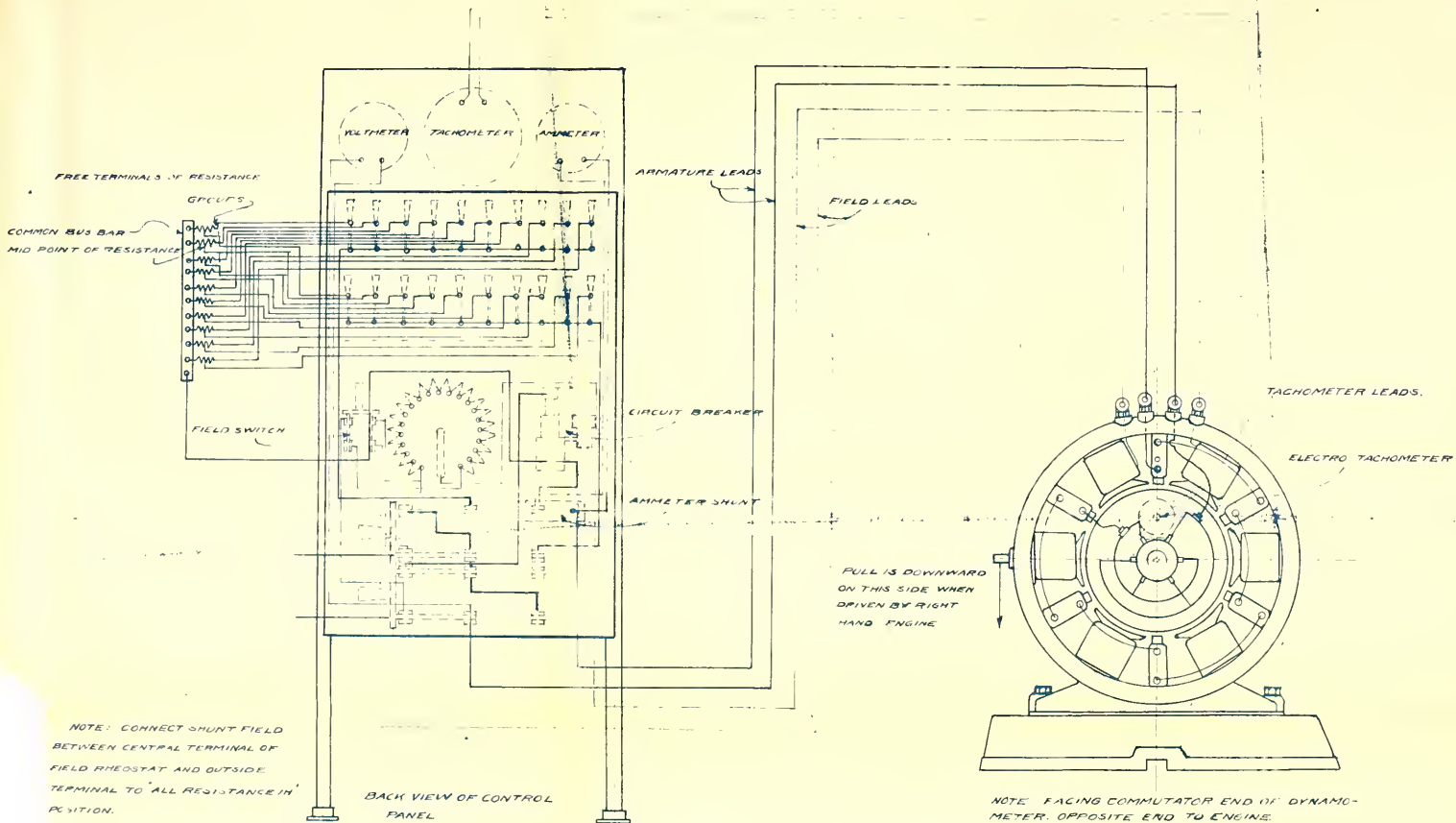
R.P.M.	Wide Open Throttle. Suction
500	$\frac{3}{4}$
675	$\frac{13}{16}$
960	$1-\frac{1}{8}$
1075	$1-\frac{3}{8}$
1300	$1-\frac{3}{4}$
1500	$2-\frac{1}{8}$
1700	$2-\frac{3}{4}$
1900	3
1925	$3-\frac{1}{8}$



FR

ION E

DOIN



WIRING DIAGRAM FOR 100 HP. SPRAGUE ELECTRO-DYNAMOMETER.

AS INSTALLED AT ARMOUR INSTITUTE OF TECHNOLOGY.
DRAWN BY: H. D. SUMNER, MAY 28, 1914





